

Basic Urologic Laparoscopy

A Standardized Guideline for Training Programs

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RESIDENT HANDBOOK

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INTRODUCTION

Laparoscopy has become the approach of choice for many of the surgical procedures on the kidney for benign and malignant urologic diseases. It is now recognized that laparoscopic training should be an integral component of all urology resident training programs. The purpose of this handbook is to provide a basic educational tool for teaching residents the concepts important to laparoscopic surgery in any urology training program. An attempt has been made to standardize the information and descriptions of the instruments and approaches through a consensus of expert laparoscopic urologists. It should be recognized that while these guidelines provide a standardized methodology they are by no means the only way to perform the procedures. Depending on the clinical situation, surgeon experience and type of surgical procedure the description of the port placement, patient positioning and instrumentation may vary accordingly. It is hoped that this manual will provide residents an overview and basic understanding of laparoscopic urology, upon which further laparoscopic training can be developed.

1. Preoperative Patient Management

Careful patient selection and identification of possible relative and absolute contraindications are vital to a successful outcome of laparoscopic procedures. To this end, a meticulous past history and physical examination is the initial step in patient evaluation for possible laparoscopic surgery. Emphasis is placed on pulmonary, cardiac, and renal status along with a careful history of prior abdominal surgery. Regarding the last, special attention should be made to elicit the following history: ruptured appendix, intra-abdominal abscess, and need for mesh hernia closure. During the physical examination, the patient should be placed in the planned surgical position to assess both body habitus and to familiarize the patient as to likely port placement. Age and health based laboratory studies, an electrocardiogram, and a chest radiograph should be obtained following the same criteria as established for any other significant open surgical procedure which necessitates general anesthesia.

Patients presenting with severe chronic obstructive pulmonary disease (COPD) require further studies (i.e. arterial blood gases and pulmonary function tests). In severe COPD, helium should be considered as an alternative insufflant. Severe cardiac arrhythmias should be evaluated and treated accordingly, as hypercarbia and the resulting acidosis may have adverse effects on the myocardium.

Absolute contraindications to laparoscopic surgery include uncorrectable coagulopathy, intestinal obstruction, abdominal wall infection, massive hemoperitoneum, and generalized peritonitis.

Relative contraindications to laparoscopic surgery necessitate careful risk benefit analysis and extensive informed consent. The following eight conditions should alert the surgeon to potential difficulties with a laparoscopic approach.

a. Morbid obesity: Laparoscopic procedures in morbidly obese patients are technically challenging. These difficulties include: inadequate length of instruments, decreased range of motion of the instruments, need for higher insufflation pressures to elevate the abdominal wall and poor anatomical orientation due to excessive amounts of adipose tissue. These difficulties translate into a higher rate of associated complications. In a multi-institutional review of laparoscopy in 125 morbidly obese individuals, one or more intraoperative or postoperative complications occurred in 30% of patients (Mendoza et al, 1996). **In a recent comparison of major laparoscopic renal and adrenal procedures (n=21) versus similar open procedures (n= 21) in the markedly obese patients (BMI, 30 or greater), although operative time was longer in the former (210 mins vs. 185 mins; p=0.16), the laparoscopic group had significantly superior outcomes with regards to blood loss (100 cc vs. 350 cc; p< 0.001), resumption of oral intake and ambulation (less than 1 vs. 5 days; p<0.001); narcotic analgesic requirement (12 mg vs. 279 mg; p<0.001), median hospital stay (less than 1 vs. 5 days; p,0.001), and convalescence (3 vs. 9 weeks; p<0.001) (Fazeli-Matin et al, 1999).**

b. Extensive prior abdominal/pelvic surgery: When extensive intra-abdominal or pelvic adhesions are suspected close attention must be given to the possible site of Veress needle insertion, as well as consideration of obtaining open access with a Hasson style cannula. Alternatively, if a renal/ureteral procedure is being planned, then in these patients, a retroperitoneal approach may be preferable to a transperitoneal approach or the procedure can be initiated retroperitoneally and the peritoneum then entered.

c. Pelvic fibrosis: Pelvic fibrosis due to previous peritonitis and/or pelvic surgery or radiation may constitute a severe technical challenge to the laparoscopic surgeon when surgery of the lower urinary tract is indicated. Similar problems may be encountered when trying to perform a pelvic lymph node dissection in patients who have undergone a hip prosthesis; leakage of the sealant can create a dense inflammatory reaction and fibrosis.

d. Organomegaly: Known or preoperatively diagnosed organomegaly necessitates a cautious approach when obtaining the pneumoperitoneum. The site of Veress needle insertion must be chosen at a safe distance from any enlarged organ(s). Alternatively, open access with the Hasson cannula may be considered. Open access is recommended in the case of marked hepatomegaly or splenomegaly.

e. Ascites: Patients with severe ascites are under increased risk of injury to the bowel due to closer proximity of bowel loops to the anterior peritoneum. In addition, a watertight wound closure is required and a firm wound dressing should be applied to prevent prolonged postoperative leakage. An open cannula approach to achieving the pneumoperitoneum in these patients is recommended.

f. Pregnancy: Initial access to the abdomen must be obtained at a safe distance from the fundus of the gravid uterus. As such, trocar placement is usually performed more cephalad on the abdominal wall, depending on the fundus of the uterus. The left upper quadrant is often the preferred site of access. Prolonged intra-abdominal pressures of ≥ 15 mm Hg may result in

hypotension due to significantly reduced venous return as the vena cava is already mechanically compromised by the enlarged uterus. Prolonged CO₂ pneumoperitoneum, which may result in maternal hypercarbia and acidosis with subsequent adverse effects on the fetus, should be avoided. Accordingly, a working pneumoperitoneum of 10 mm Hg is recommended in the pregnant patient. As pregnancy progresses beyond the 20th week, the technical possibility of performing laparoscopic procedures decreases significantly correlating with the increasing size of the gravid uterus. Both cholecystectomy and adrenalectomy have been successfully accomplished in the pregnant female (Oeslner et al, 2003).

g. Hernias: A diaphragmatic hernia may result in leakage of a significant amount of CO₂ into the mediastinum which, although rarely seen, may eventually result in clinical problems (i.e. pneumopericardium) (Knos et al, 1991).

Any evidence of uncorrected or surgically corrected umbilical hernia should rule out the umbilicus as a site for obtaining a pneumoperitoneum. The use of mesh to close an abdominal hernia precludes trocar placement anywhere within the region in which mesh was placed.

h. Iliac or aortic aneurysms: This condition needs to be evaluated by the vascular surgeons. If the aneurysm does not warrant immediate surgical correction, insertion of the Veress needle must be performed in the left or right upper quadrant in order to stay well away from the area of the aneurysm. Alternatively, open access with the Hasson technique can be employed. Insertion of accessory trocars must be done under strict endoscopic visualization in order to avoid the area of the aneurysm. Alternatively, if a renal/ureteral procedure is being planned, then the retroperitoneal laparoscopic approach can be employed.

Informed Consent:

Although laparoscopic surgery is generally associated with decreased pain and morbidity, it should be remembered that there is considerable potential for serious complications, similar to those associated with standard open incisional surgery. It is essential that the patient understand that with all laparoscopic procedures there is the inherent risk that the procedure may need to be converted to open surgery due to hemorrhage, bowel injury, failure to progress, and/or other complications at any point during the intra-or postoperative course.

All alternative forms of surgical or non-surgical treatment (if applicable) with their known advantages and disadvantages have to be discussed. The patient needs to be aware of both complications unique to laparoscopy (i.e. fatal gas embolism, problems due to hypercarbia, postoperative crepitus, pneumothorax, etc.) as well as procedure specific complications (e.g. damage to the obturator nerve in pelvic lymphadenectomy).

Time spent obtaining informed consent is well invested. It is both the patient's right and the physician's protection. A good beginning augurs a good end.

Bowel Preparation:

The need and regimen of bowel preparation has changed markedly over the past decade. For retroperitoneoscopy no bowel preparation is needed. For transperitoneal laparoscopic procedures a light mechanical bowel preparation can be given in an effort to decompress the bowel. Usually a clear liquid diet and a Dulcolax suppository or two Dulcolax tablets or a bottle of magnesium citrate the day prior to the procedure is sufficient. The need for a full mechanical (eg. GoLyteLy 2-4 liters or 3 ounces Fleet phosphorous soda / clear liquid diet / Fleets enema) and antibiotic (eg. neomycin 1g p.o. and flagyl 500 mg p.o. 3 doses of each, the day before surgery, plus 1g of intravenous cefotetan on call to the operating room) bowel preparation only becomes an issue if one is anticipating encountering dense intra-abdominal adhesions, the surgery involves entering the bowel (eg. enteric augmentation of the bladder) or if the chances of a bowel injury are increased due to the nature of the surgery (eg. early in one's experience with laparoscopic radical prostatectomy).

Preparation of Blood Products:

Blood type and screen is sufficient for diagnostic laparoscopy or procedures which are associated with a low chance of major hemorrhage (i.e. varicocelectomy and pelvic operations). More extensive laparoscopic procedures (i.e. laparoscopic nephrectomy) should be managed like any other major open surgical procedure with the availability of 2 units of packed red blood cells prior to surgery. The patient should also be provided with the option and possibility of donating 2 units of autologous blood. This is most true during one's initial experience with major laparoscopic cases. However, with experience, a type and hold suffices as the need for transfusion among patients undergoing major laparoscopic procedures such as radical nephrectomy or radical nephroureterectomy is quite low (3-12%), with an estimated average blood loss in the range of 106-255 ml.

Optional Preoperative Endourologic and Radiologic Procedures:

Preoperative CT scan, spiral 3-D CT scan, or MRI are helpful in depicting the anatomical relationship of the operative site to adjacent organs and/or blood vessels. For laparoscopic partial nephrectomy, preoperative renal arteriography provides the surgeon with an insight into the renal arterial architecture. However, spiral CT angiography with 3D reconstruction now affords the surgeon an unparalleled view of both lesion and attendant vasculature. When laparoscopic nephrectomy is performed for large (i.e. > 10 cm) malignant renal tumors, immediate preoperative embolization of the renal artery may be considered; this procedure allows the surgeon to secure and divide the renal vein earlier in the transperitoneal laparoscopic procedure. In other disease states, the preoperative placement of a percutaneous drainage catheter can be quite helpful; intraoperative filling, staining (e.g. indigo carmine) and drainage of the surgical site can aid greatly in its identification and subsequent treatment (eg. lymphocele or intrarenal cyst or calyceal diverticulum).

A variety of catheters, both opaque and light bearing, can be placed in the ureter to facilitate ureteral identification and dissection in laparoscopic nephrectomy, pyeloplasty, nephroureterectomy, ureterolysis, ureterolithotomy, and retroperitoneal lymph node dissection. Experience usually obviates the need for these preoperative preparations.

2. Setting Up The Operating Room

The operating suite has to provide enough space to accommodate all necessary personnel and the technological equipment required by both the laparoscopist and the anesthesiologist. Positioning of equipment, surgeon, assistants, nurses, anesthesiologist and other support staff should be clearly defined and established for each standard laparoscopic case. All equipment needed must be fully functional and in operating condition before any laparoscopic procedure is started. A separate tray with open laparotomy instruments in the event of complications or problems necessitating conversion to open incisional surgery must be ready for immediate use (Table 1).

Table 1.

Before making a skin incision for obtaining the pneumoperitoneum the following instruments should be checked:

- 1. Irrigation-aspiration unit working**
- 2. Electrosurgical unit working**
- 3. CO₂ tank full with extra CO₂ tank in the room**
- 4. Camera is white balanced and light source working**
- 5. Insufflation checked for flow and proper “shut-off” response to kinking the tubing.**
- 6. Veress needle checked for flow and proper tip retraction**

Patient positioning and draping:

Positioning of the patient depends primarily on the laparoscopic procedure to be performed. Most laparoscopic transperitoneal renal procedures start with the patient in a modified lateral decubitus position with the operative side slightly elevated at an angle of 30 to 45 degrees. This can be achieved by placing supports or rolls at the hip and shoulder. **The bottom leg is flexed approximately 45 degrees while the upper leg is kept straight; pillows are placed between the legs as a cushion and also to elevate the upper leg so that it lies level with the flank thereby obviating any undue stretch on the sciatic nerve.** The arms are secured in the “praying” position or on double arm boards with pillows and padding. It is very important to adequately pad the boney prominences of the hip, knee, ankle and elbow. An axillary roll is placed to reduce the risk of a brachial nerve injury. The patient is then secured to the

table with tape and/or safety belts at the hips, lower leg and shoulders such that in Trendelenburg or lateral positions of the table, the patient will not shift on the table. The point of contact between any of the positioning straps and the hip, thigh, leg or shoulder should also be padded. The table can then be flexed and the kidney rest raised dependent upon the surgeon's preference. If a kidney rest is to be used, the patient should be positioned so the kidney rest underlies the contralateral superior iliac crest. Application of active warming systems may prevent hypothermia should a lengthy laparoscopic procedure be anticipated. For lower abdominal procedures, a supine position is used. For retroperitoneal procedures, the patient is placed in a full flank (90 degree) position. Depending upon the surgeon's preference, the table may be flexed and the kidney rest raised to further open the space between the iliac crest and the rib cage.

The full extent of the abdominal wall should be prepared and draped from nipples to pubis. In some procedures, it is of advantage to extend the preparation to the knees and to drape the external genitalia into the surgical field. For example, gently pulling on the testicle may help identify the intrapelvic location of the vas deferens and spermatic vessels, insertion of ring forceps into the vagina certainly facilitates laparoscopic sacrocolpopexy, and free access to the urethral meatus enables the performance of auxiliary procedures such as flexible cystoscopy or manipulation of ureteral catheters, during a laparoscopic nephroureterectomy or for stent placement at the end of a laparoscopic pyeloplasty.

Prior to major laparoscopic procedures placement of a nasogastric tube and a Foley catheter is performed to decompress stomach and bladder, respectively, thereby decreasing the chance of injury of abdominal contents during insertion of the Veress needle and the initial trocar. Pneumatic compression stockings are applied as anti-thrombotic prophylaxis.

Strategic placement of operative team and equipment:

If only one monitor is used (i.e. intrapelvic procedures), it is typically placed at the foot of the table. If two monitors are used they are positioned on either side of the table opposite the primary and assisting surgeon, respectively, to allow an unobstructed view. Most laparoscopic surgery is now being performed with the surgeon and the assistant standing on the same side of the table and the monitor and table-mounted instrument holder (e.g. Codman Endoholder, Johnson & Johnson, Inc.) positioned on the opposite side. The secondary monitor can then be positioned anywhere in the room to facilitate viewing by the ancillary operating room staff.

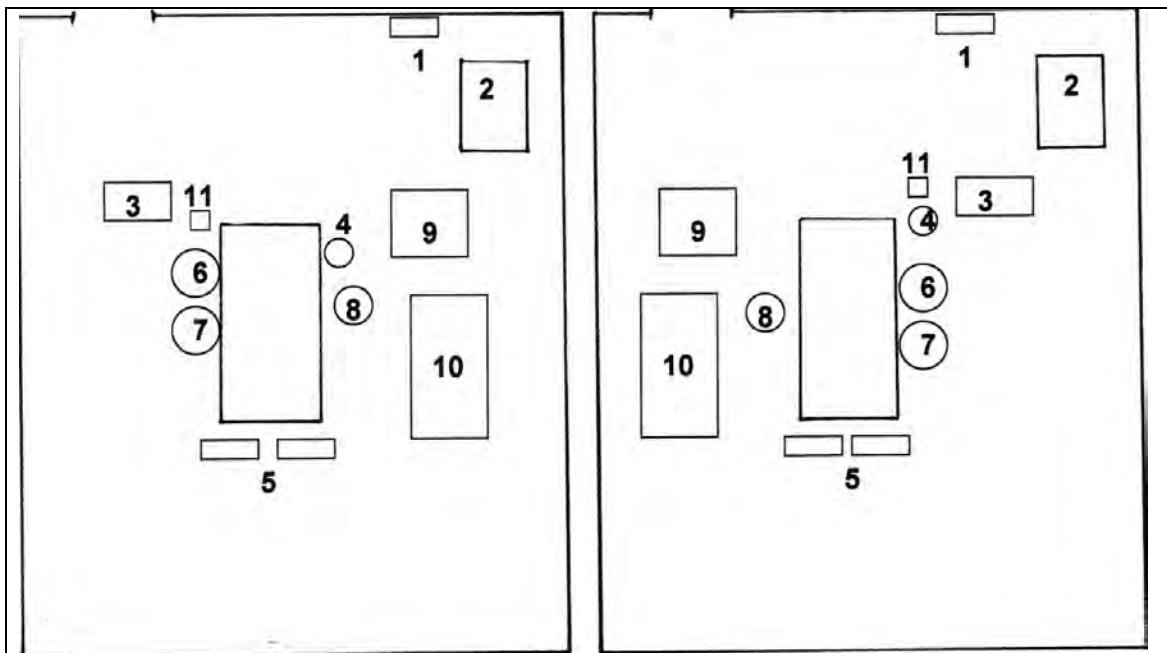
The cart or boom system holder, with the monitor for the primary surgeon, should also contain the insufflator placed at the surgeon's eye level to allow continuous monitoring of the CO₂ pressure. The light source, camera controls, and any recording device are also on this cart.

The surgeon usually stands opposite the area of surgical interest and the camera-holding assistant stands on the same side of the table as the surgeon. The second assistant has routinely been replaced by a table mounted instrument holder which is secured to the contralateral side of the table (Figure 1).

Particularly in the initial experience with laparoscopy it is recommended to place the scrub nurse on the opposite side of the table from the surgeon, with the instrument table towards the end of the table (Figure 1A, 1B, 1C, 1D). This facilitates communication between the surgeon and the scrub nurse and allows instruments to be passed more easily. Incoming lines from the insufflator, suction/irrigation, and electrosurgical devices enter from the contralateral side or foot of the table. Optional technology (i.e. harmonic scalpel, and Argon beam coagulator) must be arranged in an orderly fashion utilizing either preexisting or improvised pockets of the surgical drape. Again, these lines ideally should enter the field from the contralateral side or foot of the table or from the ipsilateral head of the table. Robotic devices for electronically or voice-controlled camera manipulation should be brought into the operative area from the contralateral side of the table to prevent any limitations of the surgeon's or assistant's maneuverability during the procedure. Additional technology (e.g. high speed electrical tissue morcellator or laparoscopic ultrasound probe) may be moved to the operating table depending on the surgeon's needs as well as availability of space.

If the surgeon will be using more than one foot-pedal during the procedure, it is helpful to develop a routine arrangement of the foot-pedals. This will facilitate use of the proper foot-pedal during the case. For instance, the electrosurgical foot-pedal can always be situated opposite the surgeon's left foot, while the harmonic foot-pedal is positioned opposite the surgeon's right foot.

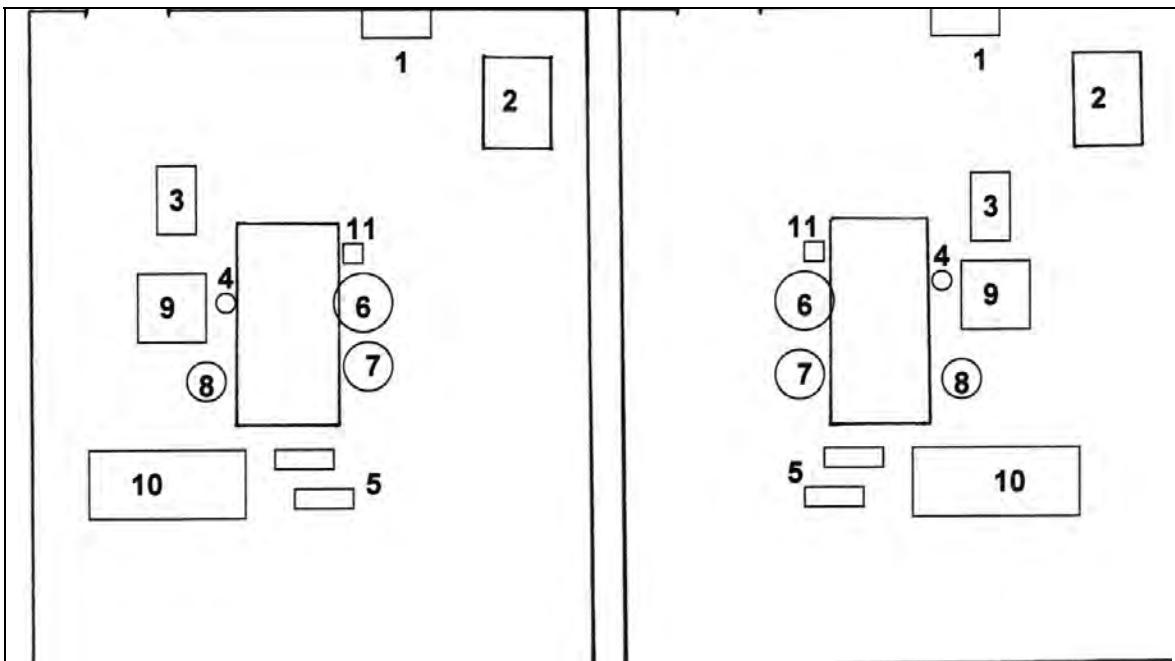
To facilitate a more comfortable positioning of the surgeon's arms, a six by four foot, 6 inch lift can be used since most operating tables can not be lowered sufficiently to allow the surgeon to hold the laparoscopic instruments with his/her arm comfortably extended, but still allowing the elbows to rest comfortable at the sides. Ideally, the distance from the floor to the patient's abdominal wall should be lower, or 0.7 of the distance from the floor to the surgeon's elbows. Use of a lift of this type, is especially helpful during laparoscopic suturing.



1A. O.R. Setup for Right Transperitoneal Renal Surgery

1B. O.R. Setup for Left Transperitoneal Renal Surgery

- 1. Wall suction
- 2. Sterile covered set-up for open procedure
- 3. Irrigation / aspiration container
- 4. Bedside attached instrument holder
- 5. Bovie / Harmonic / Argon beam coagulator
- 6. Surgeon
- 7. Camera assistant
- 8. Scrub nurse
- 9. Primary monitor, video cart, CO₂ insufflator, camera box, light source
- 10. Instrument table
- 11. Electrosurgery foot pedal



1C. O.R. Setup for Left Retroperitoneal Renal Surgery

1. Wall suction
2. Sterile covered set-up for open procedure
3. Irrigation / aspiration container
4. Bedside attached instrument holder
5. Bovie / Harmonic / Argon beam coagulator
6. Surgeon
7. Camera assistant
8. Scrub nurse
9. Primary monitor, video cart, CO₂ insufflator, camera box, light source
10. Instrument table
11. Electrosurgery foot pedal

1D. O.R. Setup for Right Retroperitoneal Renal Surgery

3. Performing the Procedure

A. Prior to the initial incision:

A check list to be certain all essential equipment is present and operational should be completed just prior to initiating the pneumoperitoneum. Specifically this should include: 1.) light cable on the table connected to the light source and operational, 2.) laparoscope connected to the light cable and to the camera; the image should be white balanced and focused on a gauze sponge, 3.) suction and irrigation (1 liter bag of normal saline with 5000 units of heparin added) are operational, 4.) the insufflator tubing is connected to the insufflator which is turned on to allow the surgeon to see that there is proper flow of CO₂ through the tubing; kinking the tubing should result in an immediate increase in the pressure recorded by the insufflator with concomitant cessation of the CO₂ flow, 5.) an extra tank of CO₂ should be in the room, 6.) the Veress needle is

checked to make sure its tip retracts properly and when connected to the insufflator tubing the pressure recorded with 2 liters/minute CO₂ flow through the needle is less than 2 mm Hg, 7.) both the handheld and laparoscopic electrocautery units should be tested to make sure they are functional, and 8.) the harmonic shears has been set up and tested to make sure it is working. If an argon beam coagulator is present, it should also be tested to make sure there is sufficient argon gas and that the electrocautery mechanism is functional. The surgeon should check to make sure other necessary procedure specific equipment is in the room (e.g. needle holders and appropriate suture material for a reconstructive procedure). A sterile but unpackaged, open tray should also be in the room.

B. Access and Positioning

Transperitoneal:

Pneumoperitoneum

The insufflant system (i.e. insufflator, tubing, and chosen gas) is essential for the establishment of a pneumoperitoneum. This is brought into use once either closed (i.e. Veress needle) or open (e.g. Hasson cannula) access to the peritoneal cavity is established.

1. Insufflant system:

Most commonly CO₂ is used as the insufflant because it does not support combustion and is very soluble in blood. However, in patients with chronic respiratory disease, CO₂ may accumulate in the blood stream to dangerous levels. Accordingly, in these patients, helium may be utilized for insufflation once the initial pneumoperitoneum has been established with CO₂ (Leighton et al, 1993). The drawback of helium is that it is much less soluble in blood than CO₂; however, its use precludes problems of hypercarbia. Other gases that have been used for insufflation (i.e. room air, oxygen, and nitrous oxide) in the past, are no longer routinely used due to their potential side effects (i.e. air embolus, intraabdominal explosion and potential to support combustion). "Noble gases" such as xenon, argon, and krypton are inert and nonflammable but are not routinely used for insufflation due to their high cost and poor solubility in blood.

To start, the insufflator pressure is set at 15 mm Hg with a rate of gas flow of 1 liter/minute. Once safe entry into the peritoneal cavity has been achieved, the flow can be increased to 2 liters/minute for the Veress needle or the maximum insufflator flow setting if a Hasson cannula has been used. The 14 gauge Veress needle can not deliver flow rates > 2 liters/minute.

The insufflated CO₂ is cold (21 degrees C) and it is not humidified (Ott et al, 1991). This can result in cooling of the patient and likely contributes to problems of fogging of the endoscope during the procedure. A new product, the **Insuflow filter** (Porous Media, St. Paul, MN) is an accessory device to insufflators which warms and humidifies laparoscopic gas to physiologic

conditions. However, the benefit of this technology has been largely of only anecdotal importance to date.

2. Closed techniques:

Disposable (70 or 120 mm, 14 gauge, and 2 mm outer diameter), as well as nondisposable (metal), Veress needles can be utilized to obtain a pneumoperitoneum. Proper needle function prior to the procedure is tested. As such, the blunt tip of the needle is tested to make sure it retracts easily; also, the needle is connected to the CO₂ line to make sure there is no resistance to CO₂ inflow. Lastly, saline is flushed into the needle with the tip manually occluded to make sure there is no leakage at the juncture between the shaft and hub of the needle.

With the patient in the supine position, the head of the bed is lowered 10-20 degrees; insertion of the Veress needle is commonly accomplished at the inferior or superior border of the umbilicus. If the patient is in a lateral decubitus position, then the Veress needle is passed two fingerbreadths medial and two fingerbreadths superior to the anterior superior iliac spine; palpation along this area reveals a vertically placed "hollow" or furrow in the underlying abdominal musculature. Just prior to insertion of the Veress needle, a 12 mm incision is made in the aforescribed area, in anticipation of placing a 10-12 mm trocar. The subcutaneous tissues are spread with a Kelly clamp and the anterior fascia is secured with an Allis clamp. The abdominal wall is stabilized by slightly lifting the Allis clamp. The Veress needle is grasped at midshaft and is passed through the anterior fascia using a gentle, steady pressure. The tip of the needle, when passed transumbilical, is directed 20 degrees toward the pelvis away from the intestines; alternatively in the morbidly obese patient a more perpendicular route is used. When the patient is in a flank position, the needle is passed directly perpendicular to the peritoneum. Two points of resistance are traversed: the abdominal wall fascia and the peritoneum.

Several tests are performed to ensure that the Veress needle has properly entered the peritoneal cavity.

a. Aspiration/Irrigation/Aspiration:

Using a 10cc syringe containing 5 cc of saline the Veress needle is aspirated to check for blood or bowel contents. If this is negative, then the saline is injected into the abdominal cavity; this should occur without any resistance. Next, the plunger of the syringe is again withdrawn; no fluid should return into the barrel of the syringe. At this point, 2-3 cc of fluid are again injected in order to clear any tissue that may have been aspirated into the tip of the needle. Lastly, the syringe is detached from the Veress needle; any fluid left in the hub of the needle should fall swiftly into the peritoneal cavity.

b. Hanging drop test:

If there are any questions about the proper placement of the needle in the peritoneal cavity, a drop of saline can be placed on the hub of the Veress needle. The drop should fall swiftly into the spacious peritoneal cavity as the abdominal wall is lifted by the Allis clamps.

c. Advancement test:

If the needle has truly just entered the peritoneal cavity, then the surgeon ought to be able to advance the needle 1-2 cm deeper without the tip meeting any resistance, as indicated by no movement of the red indicator on the Veress needle hub. Resistance at this stage usually means the needle is still in the preperitoneal space and needs to be advanced (Figure 2).

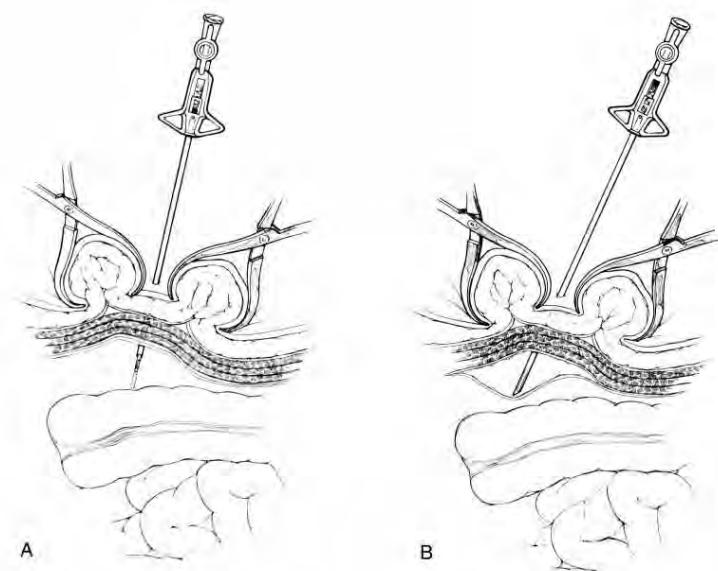


Figure 2 Advancement test. A, When the Veress needle is placed correctly inside the abdominal cavity, the tip can be advanced for 1 to 2 cm without encountering resistance; the red indicator in the hub of the needle does not move, indicating a lack of resistance to needle advancement. The atraumatic tip of the needle is extended. B, If the Veress needle is in the preperitoneal space, any attempt at further advancement is met with increasing resistance, indicating incorrect placement. Also, the indicator in the needle's hub moves up, indicating that the sharp surface of the Veress needle is exposed. (From Walsh PC, Retik AB, et al (eds): Campbell's Urology. Philadelphia, Saunders, 2002)

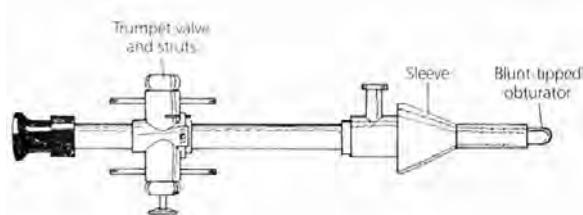
Finally the proper needle placement is verified as insufflation is started at 1L/min. If free flow of CO₂ is noted (i.e intraabdominal pressure remains less than 10 mm Hg) after 0.5 L has entered the abdomen, the flow can be increased to maximal capacity. As soon as the preset limit of 15 mm Hg of intraabdominal pressure is reached, free flow will stop.

In a previously operated abdomen, Veress needle insertion should be performed in an unscarred quadrant of the abdomen, preferably the left upper

quadrant. Alternatively, if there is no “scar free” area, then an open technique should be used.

3. Open technique:

Pneumoperitoneum can be most easily and safely established using an open technique; however, its use involves making a larger incision and increases the chances of port site gas leakage during the procedure. **When extensive adhesions are anticipated a Hasson-style cannula is usually the preferred means of obtaining peritoneal access (Figure 3A). Studies in general surgery have shown the open technique to be as efficient as the closed approach and slightly safer.**



A.



B.

Figure 3 Hasson Cannula: nondisposable (A) and disposable balloon tip port (B). (From Clayman RV, McDougall EM (eds): Laparoscopic Urology. St. Louis, Quality Medical Publishing, 1993)

In the unscarred abdomen, a 2-cm semicircular incision is made at the lower edge or slightly below the umbilicus. The fascia and peritoneum are opened individually with a 2-3 cm transverse incision, sufficient to accommodate the surgeon's index finger. After visual and digital confirmation of entry into the peritoneal cavity, two, 0-silk traction sutures are placed on either edge of the fascia. Next, the Hasson cannula is advanced through the incision with the blunt tip protruding. The funnel-shaped adapter of the Hasson cannula is then advanced until it firmly rests in the incision and is tightened onto the cannula with the attached screw. Fixation to the abdominal wall is accomplished by using the fascial sutures which are wrapped around the struts on the funnel shaped adapter of the Hasson cannula, thereby anchoring it in place. Alternatively, the disposable balloon tip, Bluntport (US Surgical Corp, Norwalk, CT), can be inserted through the peritoneotomy into the abdominal cavity (Figure 3B). The retention balloon at the end of the port is inflated with 30 cc of air and an external adjustable foam cuff is locked down against the abdominal wall, effectively creating an airtight seal at the location of the primary port site. After removal of the obturator, free flow of CO₂ into the peritoneal cavity is achieved by attaching the insufflation tubing to the cannula. The insufflator can be set at maximum inflow, thereby creating the pneumoperitoneum quickly.

4. Alternative technique:

Utilizing the Endopath "Optiview" (Ethicon Endo-Surgery, Cincinnati, OH) is another option in obtaining a "closed" pneumoperitoneum. However, this port should also be placed after a satisfactory pneumoperitoneum has been established. The tip of this 12 mm trocar system is transparent and allows direct visualization of each tissue layer as it is traversed. This type of access is a hybrid between the closed and open techniques for obtaining a pneumoperitoneum, since the peritoneal cavity is entered under optical control while the length of the incision needed for access is identical to the closed Veress needle technique.

5. Hand-assisted laparoscopy (HAL) technique:

The hand-assisted approach seems very appropriate for those patients in whom an open incision may be required for removal of an intact specimen, such as the laparoscopic nephroureterectomy for transitional cell cancer of the upper tract and the laparoscopic live donor nephrectomy. Some investigators have also shown that the use of a hand-assisted device may reduce the operative time in technically challenging procedures and may assist surgeons in acquiring the technical skills necessary for performing laparoscopic removal of large intra-abdominal organs (Schichman et al, 1998). As such, this approach may increase the availability of this minimally invasive surgery to the general community patient.

There are a variety of commercially available hand-assist devices. While all are slightly different in their design, they all provide a seal at a mini-laparotomy incision to maintain the pneumoperitoneum while providing access for one of the surgeon's hands intra-abdominally. The HAL devices presently available include: the HandPort by Smith & Nephew; the GelPort by Applied Medical; the Omniport by Weck; and the LapDisc by Ethicon Endosurgery Inc.

Prior to positioning, with the patient in a supine position, the planned line of incision for the HAL device is drawn out on the abdomen. The patient is positioned in a similar manner as for the transperitoneal pure laparoscopic renal surgery, a modified lateral decubitus position. Supports under the hip and shoulder maintain this positioning intra-operatively. The hand-assist device is inserted to maximize the ability of the intra-abdominal hand to provide retraction and dissection without interfering with the visualization provided by the laparoscope. For right-sided renal surgery by a right-handed surgeon, the HAL device maybe positioned at and just below the umbilicus. For the left-sided renal surgery by a right-handed surgeon, the HAL device maybe positioned at and just above the umbilicus. The hand-assist device can be inserted initially or after establishment of the pneumoperitoneum. If the former approach is chosen the skin, fascia and peritoneum are incised in the length and position to accommodate the surgeon's hand comfortably. The length of the incision in centimeters is usually the same as the surgeon's glove size (i.e. a surgeon with a

size 7 glove size would use a 7cm skin incision for the hand-assist port). Following placement of the HAL device the working pneumoperitoneum is established and the additional ports are placed under digital palpation in the abdominal wall.

Alternatively, the pneumoperitoneum may be established by Veress needle insertion on the anterior-axillary line at the level of the anterior iliac crest. A 12mm port is placed at this site and the 30 degree, 10mm laparoscope is inserted to visualize the abdominal wall at the umbilicus and midline. The pneumoperitoneum can then be increased to 25mm Hg. The skin, fascial and peritoneal incisions are then performed with the pneumoperitoneum and laparoscopic visualization. This technique results in a shorter skin incision when the abdomen is desufflated and allows for a very precise dissection and incision of the abdominal wall layers due to the pneumoperitoneum and back lighting of the laparoscope. The HAL device is applied at the mini-laparotomy incision according to the manufacturer's instructions. If the patient is obese it is important to use the HAL device designed for a large body habitus. For most of the modern HAL devices a special sleeve is not necessary when utilizing this equipment. However, wrapping the surgeon's forearm with a self-adherent plastic drape may facilitate passage of the arm deeper into the abdomen during the procedure. The pneumoperitoneum is reduced to 10 - 15 mm Hg. Additional working ports are placed appropriately under combined digital palpation and laparoscopic visualization.

Retroperitoneal

Retroperitoneoscopy for renal surgery requires the patient to be positioned in a full lateral decubitus position with the affected flank elevated. It is also helpful to have the kidney rest elevated and the table flexed to maximize the exposure of the space between the costal margin and the superior iliac crest. It is very important to thoroughly pad all boney prominences and secure the patient to the table with tape and straps so the table may be safely rotated during the operative procedure to facilitate exposure of the tissues of the retroperitoneum. Again, all pressure points and strap-patient contact points are well padded.

The open Hasson technique is the most commonly employed technique for retroperitoneal access, because it affords the greatest precision during development of the retroperitoneal space. Initial access is obtained through a 20 mm, transverse incision just below the tip of the 12th rib. The posterior layer of the lumbodorsal fascia is incised, and the muscle fibers are split with a Kelly forceps, and retracted with a pair of S-retractors, to expose the posterior layer of the lumbodorsal fascia. The retroperitoneal space is entered by sharply or bluntly piercing the fascia digitally or using a hemostat. Index finger palpation of the belly of the psoas muscle posteriorly, the Gerota's fascia-covered inferior pole of the kidney anteriorly and the under surface of the 12th rib confirms proper entry into the retroperitoneal space. The index finger is employed to digitally create a space in this precise location for placement of the balloon dilator. Thus, balloon dilation is performed anterior to the psoas muscle and fascia and outside of and posterior to Gerota's fascia. The balloon dilator is inserted in a cephalad

orientation from the insertion site and inflated to the maximum capacity and then deflated. The balloon dilator may be re-inserted in a caudad direction from the primary insertion site and re-inflated to further expand the operative space and facilitate dissection of the ureter.

A commercially available trocar-mounted Silastic balloon dilator (U.S. Surgical Corp./Tyco, Norwalk, CT) is commonly employed to gain access to the retroperitoneum. The transparent, high-tensile strength silicone balloon is inflated with a sphygmomanometer bulb insufflator using room air. The balloon may be inflated up to 800 cc depending on the amount of preperitoneal fat and the age and size of the patient: 400 to 600 cc in the pediatric patient and 800 cc in the adult patient. A primary advantage is that the balloon is affixed to the end of a stiff, hollow, transparent, plastic shaft. The shaft allows precisely directed placement of the balloon dilator in the upper or lower retroperitoneum, as desired. Gradual distention of a balloon dilator in the preperitoneal space atraumatically disrupts preperitoneal connective tissue septa and displaces the mobile fat and peritoneum relative to the immobile body musculature, thus creating a generous working space. Progress of the dilation process can be endoscopically monitored, as the laparoscope can be passed inside the balloon during its inflation. Various home-made balloon dilators are also available, less expensive, but less convenient to use.

Retroperitoneoscopy is associated with unique anatomic orientation and a relatively restricted initial working area compared with transperitoneal laparoscopy. This results in a steeper learning curve with the former technique. Moreover, the fact that a comparatively limited space is available necessitates precise accuracy regarding the strategic placement of ports. The degree of technical difficulty increases in the presence of large-sized specimens. Additionally, retroperitoneoscopic entrapment of these larger specimens may be difficult. The latter problem can be overcome by laparoscopically creating an intentional peritoneotomy at the end of the procedure to allow entrapment of the specimen within the larger peritoneal cavity. Laparoscopic reconstruction and intracorporeal suturing are technically demanding procedures; in the retroperitoneal space, reconstruction can be more challenging compared with transperitoneal laparoscopy, again due to the limited space and the angle of approach to the surgical site.

C. Types of trocars:

Trocars enable the laparoscopist to introduce working instruments into the gas-filled abdomen. They also maintain or reestablish a pneumoperitoneum by conveying the insufflant and may serve as pathways for delivering dissected tissue from the surgical area to the outside of the abdomen. Typically, a trocar consists of an **outer hollow sheath** (also called cannula or port) and an **inner sharp obturator**, which is removed as soon as the outer sheath has entered the peritoneal cavity (Figure 4).

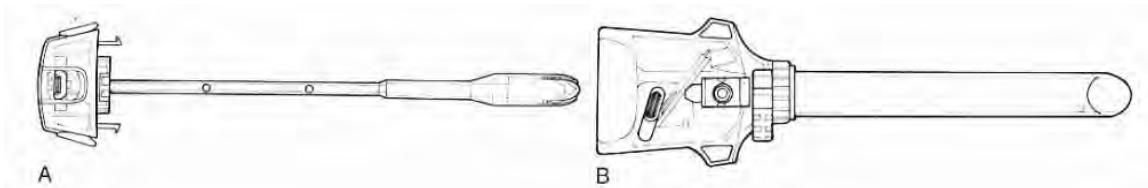


Figure 4 Laparoscopic trocar (disposable). Obturator with built-in safety shield (A) and cannula (B). (From Walsh PC, Retik AB, et al (eds): Campbell's Urology. Philadelphia, Saunders, 2002)

A variety of trocars, both **non-disposable** and **disposable**, have become commercially available. Standard models range from 3 to 20 mm in diameter and 5 to 15 cm in length. A variety of **valves** allow the surgeon to exchange instruments through the port without the escape of significant amounts of gas. Trapdoor or flap valves are found in disposable ports; as such during retrieval of tissue or needles, it is necessary to depress the valve lever in order to open the valve widely so the tissue or needle can be removed from the trocar. A trumpet valve design is used in reusable trocars; the drawback to this valve is that it can be abrasive on the insulation of electrosurgical laparoscopic instruments. Other valve configurations include slit valves and variable diameter seals; these valves are of greatest advantage when used in ≥ 10 mm trocars as they allow passage of 5 mm and 10 mm instruments without the need for using a separate "reducer".

The obturator's **sharp tip** may be conical, pyramidal, eccentric, or needle-like in design to enable the trocar to penetrate through the various layers of tissue and enter the peritoneal cavity. There is evidence to suggest that use of a conical obturator results in less tissue damage, decreased vascular injury, and possibly fewer postoperative hernias; however, passage of this type of trocar requires more force than with the sharper pyramidal style trocars. A plastic **safety shield** covers the sharp tip of most disposable trocars. It retracts as the tip of the obturator traverses the abdominal wall, but springs forward and locks in its deployed position as soon as the trocar enters the peritoneal cavity, thereby protecting intraperitoneal contents from injury. The use of a safety shield is of greatest benefit during placement of the initial trocar into a "closed" pneumoperitoneum (Figure 4A). In contrast, Hasson-style trocars, used for an "open" accesss technique, have **blunt tips** as they are only used after incisional access into the abdominal cavity is already established.

Several **new** and **innovative trocar systems** and **devices** have been recently introduced into the clinical practice of laparoscopy. A. The **EndoTip™ system** (Karl Storz, Culver City, CA) is a screw-like non-disposable device, which has no sharp points or cutting edges. It is introduced by rotating the cannula in a controlled manner with the laparoscope monitoring the penetration of the various tissue layers. As opposed to trocars with a sharp tip, the tissue is not cut, but only displaced and bluntly dilated, thereby preserving the closing mechanism of the fascia. Due to its innovative design it is said to reduce injury to the intraabdominal organs, stays securely in place, and seals the point of entry against any inadvertent loss of gas. Also upon its removal, the fascia does not need to be sutured. b. The non-disposable **Step™ Needle/Sleeve (InnerDyne, Inc, Sunnyvale, CA)** is a needle port with the outer diameter of 2.1 mm and

incorporates a Veress needle introducer. After correct and successful puncture of the abdomen and establishment of the pneumoperitoneum the Veress needle introducer is removed and the needlescopic port serves either as a camera bearing sheath for a 1.9 mm needlescope or as a working port for needlescopic scissors or graspers used to perform needlescopic surgery. c. The disposable **One-Step™ port** (InnerDyne, Inc, Sunnyvale, CA) has an adjustable seal which allows introduction of laparoscopic instruments within a range of 4.4 to 12 mm in diameter. Siloxane™ coating provides smooth passage of instruments and a removable cap facilitates removal of tissues. The initial passage of this port is facilitated by its narrow profile: 2.1 mm at the distal tip and 3.8 mm along the main body; next a blunt tipped obturator is introduced in order to expand it to a 5mm,10 mm or 12 mm size, dependent upon the surgeon's needs. As such, the tissues of the abdominal wall are stretched rather than incised thereby precluding the need for placement of fascial sutures at the end of the procedure. d. "Blunt trocars" are now being supplied by all of the major laparoscopic companies (e.g. Endopath Bladeless Trocar – Ethicon EndoSurgery Inc.). These trocars have no safety shields and are nonbladed. They are passed through the abdominal wall either with a rotating or side to side forward action. Because they dilate and stretch the abdominal wall tissues, rather than cutting the tissue, no fascial sutures are used to close these port sites, especially if they are off the midline.

All primary and some secondary trocars have **sidewall insufflation line input valves** and a small **distal hole** at the tip to prevent formation of a vacuum which may suck viscera into the cannula when the cannula is removed. Some less expensive, smaller trocars do not have sidewall stopcocks and can only be used as secondary trocars. **Reducers** allow downsizing of working channels in $>/= 10$ mm trocars to accommodate smaller 5 mm working instruments without any leakage of CO₂; however the development of multiport technology has resulted in valves that can accommodate 5 mm to 12 mm instruments without the need for a reducer. The latter development saves significant time during a long procedure. Different **retention mechanisms** prevent dislocation of cannulas: threaded sleeves, adjustable threaded sleeves, expandable arm, and inflatable balloons have largely precluded the need for trocar fixation to the abdominal wall with #2 nonabsorbable stay sutures.

When reusable trocars are used, they must be checked frequently. The obturator needs to be sharp; if dull, it should be sent to the company to be resharpened. The trumpet valve needs meticulous care, cleaning and inspection after each procedure. In an effort to simplify trocars while reducing expense, modular trocars have become available; the obturator and cannula are nondisposable while the valve part of the trocar is replaced after each case.

Presently, in many operating rooms throughout the country, sharp trocars have been removed. All access is then obtained with blunt trocars thereby largely precluding problems of injury to abdominal wall vessels, trauma to retroperitoneal vessels, and port site herniation. Unfortunately, at this time, reusable blunt trocars are presently available only from one company (Endotip, Karl Storz, Inc., Culver City, CA).

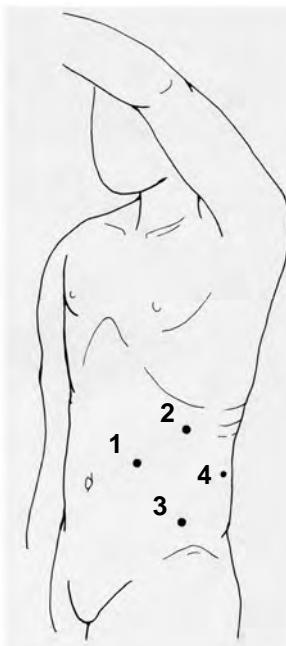
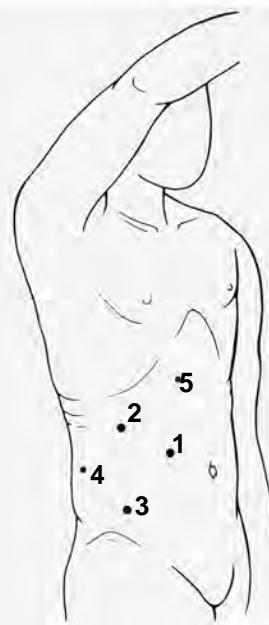
D. Port Placement

Transperitoneal Left

The placement of ports for a transperitoneal left laparoscopic renal surgery is depicted in Figure 5B. The 10/12mm laparoscopic port is placed on the mid-clavicular line just at or above the upper border of the umbilicus. A 10/12mm working port is positioned a finger-breadth below the costal margin on the anterior axillary line. A second working port, which may be a 10/12mm or a 5mm port, is placed on the anterior axillary line just above the superior iliac crest. An additional working port may be placed on the mid-axillary line mid-way between the costal margin and the superior iliac crest to provide access for a retracting instrument to mobilize the kidney laterally. This maneuver helps to put the renal vasculature on stretch and facilitates the dissection of the renal artery and vein. This port placement is most appropriate for the obese and morbidly obese patients. For the extremely thin patient the port sites are all moved medially with the laparoscope at the umbilicus, the working ports on the mid-clavicular line and an additional port on the anterior axillary line (Figure 5D). In the initial experience with laparoscopy it may be prudent to utilize larger sized ports (i.e. 10/12mm) and more ports to allow flexibility of moving the laparoscope and instruments to different ports to facilitate performing the procedure. With experience the number and size of the ports will progressively decrease.

Transperitoneal Right

The port placement for a transperitoneal right laparoscopic renal surgery is similar to that for the left side (Figure 5A). The 10/12mm laparoscopic port is placed on the mid-clavicular line just at or above the upper border of the umbilicus. A 10/12mm working port is positioned a finger-breadth below the costal margin on the anterior axillary line. A second working port, which may be a 10/12mm or a 5mm port is placed on the anterior axillary line just above the superior iliac crest. A 5mm port is placed in the epigastric region on the midline to provide retraction of the liver anteriorly and medially for exposure of the upper pole region of the kidney. An additional 5mm port may be necessary on the posterior axillary line, mid-way between the costal margin and the superior iliac crest, to provide retraction of the kidney laterally. For the extremely thin patient the port sites are all moved medially with the laparoscope at the umbilicus, the working ports on the mid-clavicular line and an additional port on the anterior axillary line. (Figure 5C and 5D)



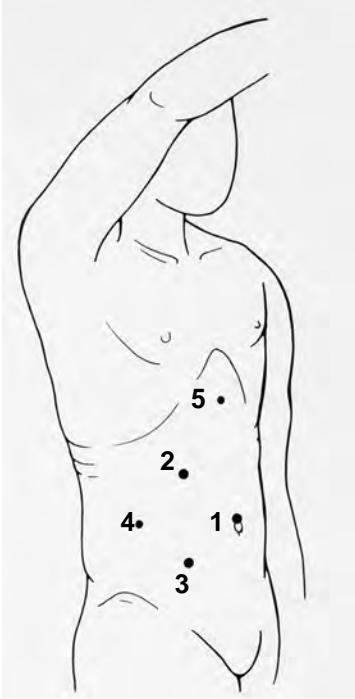
5A. Right Transperitoneal Port Placement

1. 10/12mm laparoscopic port
2. 12mm working instrument port
3. 10/12mm working instrument port
4. 5mm retractor port (optional)
5. 5mm liver retractor port

5B. Left Transperitoneal Port Placement

1. 10/12mm laparoscope port
2. 12mm working instrument port
3. 10/12mm working instrument port
4. 5mm retractor port (optional)

Figure 5 A, Port placement for transperitoneal laparoscopic left renal surgery. B, Port placement for transperitoneal laparoscopic right renal surgery.



5C. Alternate Right Transperitoneal for thin patient <ol style="list-style-type: none"> 1. 10/12mm laparoscopic port 2. 12mm working instrument port 3. 10/12mm working instrument port 4. 5mm retractor/working instrument port 5. 5mm liver retractor port 	5D. Alternate Left Transperitoneal for thin patient <ol style="list-style-type: none"> 1. 10/12mm laparoscopic port 2. 12mm working instrument port 3. 10/12mm working instrument port 4. 5mm retractor/working instrument port 5. 5mm liver retractor port
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Retroperitoneal Right and Left

Access to the retroperitoneal space is obtained through the 15-20mm incision just below the tip of the 12th rib. Additional secondary ports are then placed along the inferior border of the costal margin using digital palpation of the costal margin through the balloon dilation incision site (Figure 6A, 6B). After digital placement of all the secondary ports, the primary balloon-tip port is inserted and secured in the retroperitoneum and insufflation is established at the necessary working pressure of 10 to 15mmHg. The posterior secondary 12mm port is placed at the lateral border of the paraspinal muscle along the inferior border of the 12th rib. An anterior port is placed near the anterior axillary line, just below the inferior tip of the 11th rib. An additional 5mm port may be placed, on the mid-axillary line at or above the level of the superior iliac crest, and used for retraction and suction. Often a 12 mm port is placed at Petit's triangle just above the midportion of the iliac crest and a fingerbreadth superior to the iliac crest.

The port size is determined by several factors including, the anticipated technical difficulty of the procedure, patient obesity, and tumor size. A 12mm port is routinely placed for the surgeon's dominant hand to allow inter-changeable use

of various large-caliber instruments, including a 12mm EndoGIA stapler and a 10mm right-angle dissector. The secondary ports should be inserted as far apart as possible to minimize the probability of instrument tips clashing within the retroperitoneum.

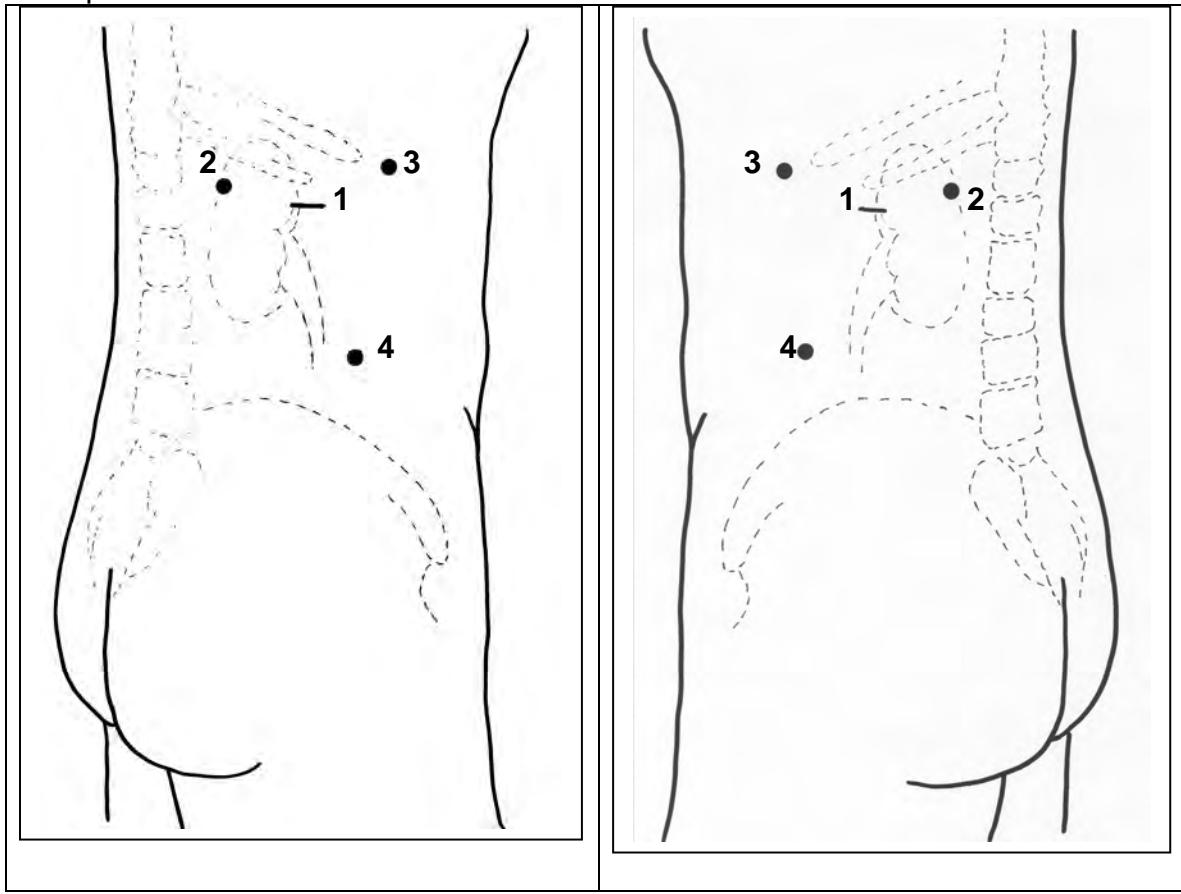


Figure 6 A, Port placement for retroperitoneal laparoscopic right renal surgery. B, Port placement for retroperitoneal laparoscopic left renal surgery

- 1 Initial access for balloon dilation of the retroperitoneum and the Bluntpoint site
- 2 12mm working instrument port
- 3 12mm or 5mm working instrument port
- 4 5mm working port for a retracting instrument

Hand-Assisted Laparoscopy Right

The location of the hand-assist device for right renal surgery is at and just below the umbilicus on the midline (Figure 7A). Alternatively, on the right side the hand port may be placed as a Gibson incision in the right lower quadrant (Figure 7C). A 10mm port is placed on the mid-clavicular line just above the superior iliac crest; the 10mm laparoscope is positioned at this port site. This site may be used for the initial insufflation and port placement before the HAL device is inserted. A 12mm port is placed 2 finger breadths below the costal margin on the mid-clavicular line, to accommodate the EndoGIA stapling device. A 5mm port is placed on the mid-line in the epigastric region for placement of an instrument to retract the liver superiorly and medially.

Hand-Assisted Laparoscopy Left

During laparoscopic surgery on the left side, using the hand-assist technique, the incision for the HAL device is located on the midline, at and above the umbilicus (Figure 7B). Insufflation may be initially performed on the mid-clavicular line just above the superior iliac crest, and then a 10mm port placed for positioning of the 10mm, 30 degree laparoscope. The laparoscope may then be used for visualization of the HAL device incision. An additional 12mm working port is placed on the mid-clavicular line 2 finger breadths below the costal margin. Retraction of the kidney laterally may be facilitated by an instrument placed through a 5mm port in the mid-axillary line, mid-way between the costal margin and superior iliac crest.

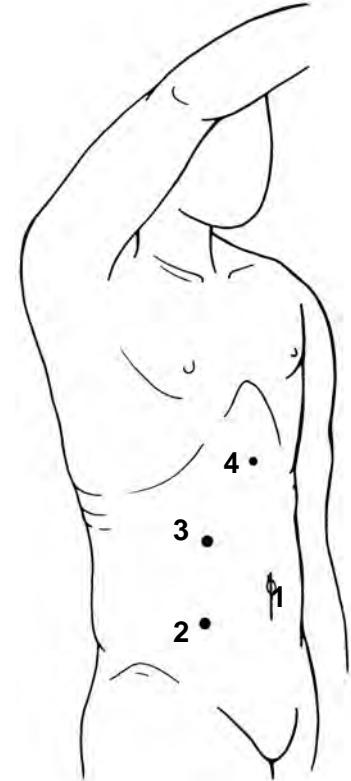
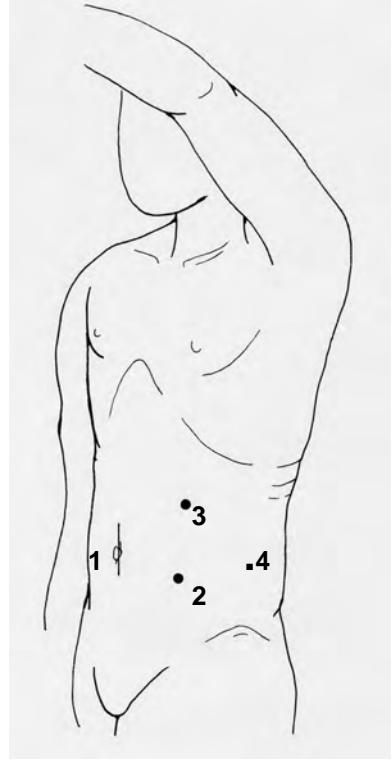
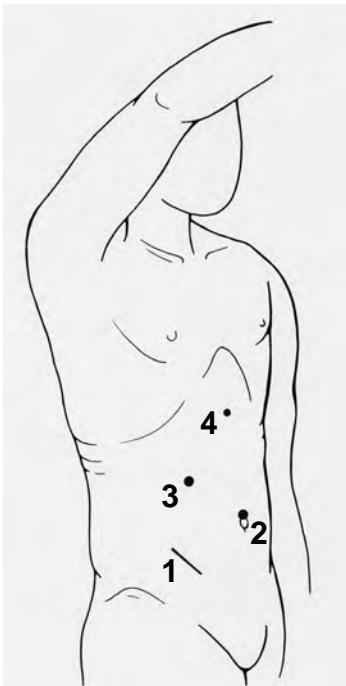
	
7A. Right HAL Port Placement <ol style="list-style-type: none">1. Incision site for the hand-assist device2. 10/12mm laparoscope port3. 12mm working instrument port4. 5mm liver retractor port	7B. Left HAL Port Placement <ol style="list-style-type: none">1. Incision site for the hand-assist device2. 10/12mm laparoscope port3. 12mm working instrument port4. 5mm working/retractor port

Figure 7 A, Placement of the incision for the hand-assist device and the ports for hand-assisted laparoscopic right renal surgery. B. Placement of the incision for the hand-assist device and the ports for hand-assisted laparoscopic left renal surgery.



7C. Alternate Right HAL Port Placement

1. Incision site for the hand-assist device
2. 10/12mm laparoscope port
3. 12mm working instrument port
4. 5mm liver retractor port

E. Instruments

1. Instrumentation for visualization

To create a laparoscopic image, four components are required: **laparoscope**, **light source**, **camera**, and **monitor**. To record the image, videocassette, CD, and DVD recorders along with video recorders and video printers are available. **Laparoscopes** that are most commonly used have 0 - or 30 - degree lenses (range 0 - 70 - degree lenses) and a size of 10 mm (range 2.7 to 12 mm). The image transmission consists of an objective lens, rod-lens system, with/without an eyepiece and a fiberoptic cable. The advantage of the larger laparoscopes is that they are able to provide a wider view, better optical resolution, and a brighter image. From the eyepiece the optical image is magnified and transferred to the camera and onto the monitor. Light is transmitted from the light source through the fiberoptic cable onto the light post of the laparoscope. A special variant is the offset "working laparoscope" which includes a working channel for passage of basic laparoscopic instrumentation; the use of this type of laparoscope enables the surgeon to work in direct line with the image and may allow for a reduction in the number of trocars needed to accomplish a particular procedure. However, the working channel occupies

space which would otherwise be used for the optical system; hence, the resulting image is usually of lesser quality when compared to laparoscopes without this feature.

The **camera system** consists of a **camera** and a **video monitor**. All currently made cameras can be gas or soak sterilized. The camera is attached directly to the end of the laparoscope and transfers the view of the surgical field through a cable to the camera box unit. After reconstruction of the optical information, it is displayed on 1 or 2 video monitors.

A wide variety of cameras is currently available: single-chip, single-chip/digitized, 3-chip, 3-chip/digitized, interchangeable fixed focus lenses, zoom lenses, beam splitter, and direct coupler. Direct couplers are superior to beam splitters, in which light and image is shared between monitor and eyepiece and in which the surgeon may view the area of interest directly through the laparoscope. Three-chip cameras are superior to single-chip cameras in that they provide a higher quality image with superior color resolution. Digitized images are preferable to analog as their recorded fidelity is preserved.

In order to obtain a "true" upright image of the surgical field on the monitor, the camera's orientation mark must be placed at the 12 o'clock position. With 0 - degree laparoscopes, the camera is locked to the eyepiece in the "true" position; the system is maintained in this orientation throughout the procedure. If the assistant inadvertently rotates the laparoscope, the image will also rotate which can be very disorienting. . In contrast, with the 30 - degree laparoscope, the camera is loosely attached to the eyepiece of the laparoscope so the laparoscope can be rotated. Accordingly, the assistant must hold the camera in the upright, "true", position with one hand, while rotating the laparoscope through a 360 degree arc in order to peer over and around vascular and other intraabdominal structures; the 30 degree lens thus provides the surgeon with a more complete view of the surgical field than a 0 degree lens.

The most vexing problem with regard to the laparoscope is "fogging" of the lens. To prevent fogging of the laparoscope after insertion into the warm intraperitoneal cavity, it is advisable to initially warm the laparoscope in a container holding warm saline prior to its passage into the abdomen. In addition, wiping of the tip with a commercial defogging fluid or with Betadine solution is also recommended. Should the image remain poor, the endoscopist should check for moisture build-up occurring between the eyepiece and the camera, both components need to be disconnected and carefully cleansed with a dry gauze pad.

Video monitors are available in 13 - or 19 - inch sizes. A larger monitor does not produce a better picture, indeed, given the same number of lines on both monitors, a higher resolution image is obtained with the smaller screen. To obtain a better image, more lines of resolution are needed. High resolution monitors with 1125 lines of resolution must be matched with a camera system of similar capability.

Light sources use high intensity halogen, mercury, or xenon vapor bulbs with an output of 250 to 300 watts. In addition to manual control of the brightness, some units also have automatic adjustment capabilities to prevent too

much illumination that may result in a “washed-out” image. Any breakage of fibers in the fiberoptic cable, which may occur during sterilization and/or improper handling, will result in decreased light transfer from the light-source to the laparoscope.

Videocassette recorders (VCRs), video disk recorders and video printers serve for documentation of laparoscopic procedures. VCRs use 1/2 - or 3/4 - inch tapes. Super VHS 1/2 - inch tapes are equal in quality to 3/4 - inch tapes but require super VHS recorders to optimally display the image. Video printers can produce up to 9 separate images while video disk recorders can store hundreds of images for subsequent editing and printing. Direct recording onto CD and DVD formats is now possible with many of the latest laparoscopic cameras.

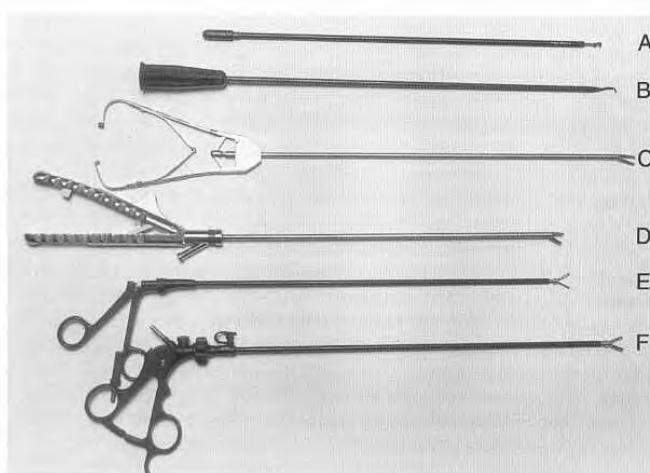
2. Instrumentation for grasping and blunt dissection

Most graspers and dissectors are used in the 5-mm size but are available in a range from 3-12 mm, in both disposable and reusable forms. Grasping instruments either have a single action (only 1 jaw moves during opening) or double action (both jaws move) tip design.

Wide variations exist with regard to configuration of tip, surface characteristics of the jaws, handle design and possible electrosurgical properties. Various tip designs include blunt-coarse, pointed (i.e. dolphin), straight (i.e. duck bill), curved (Maryland), and angled. The surface of the jaws may be atraumatic or traumatic. Serrated or smooth surfaces provide for gentle tissue manipulation in atraumatic graspers (e.g. bowel forceps); other forceps have disposable soft inserts that are changed after each case (i.e. A-Trac Laparoscopic Grasping System, Applied Medical Laguna Hills, CA). Traumatic graspers have toothed or clawed surfaces on their jaws in order to allow them to grasp and hold tissues firmly. In addition, they may be equipped with tip-rotating and articulating features.

Depending on the design of the handle, grasping instruments may be locking or nonlocking. Most nonlocking forceps have a scissor-type handle. Different designs allow for locking capabilities; in particular bar-type and spring loaded locking handles are convenient when prolonged grasping of a tissue is required (Figure 8).

Figure 8 Laparoscopic ultrasonic knife (A), hook electrode (B), needle drivers (C and D), and graspers (E – nonlocking and F – locking).



Grasping forceps equipped with electrosurgical features are insulated, which enables the surgeon to use these instruments for grasping and coagulation. The insulation must be checked frequently for any signs of damage to avoid local or transmitted thermal injury to other surrounding tissues or organs.

3. Instrumentation for incising and hemostasis

Laparoscopic scissors, scalpels, electrocautery, and laser (CO_2 , Nd:YAG, or KTP) are currently in use to incise or cut tissue during laparoscopic surgery.

Laparoscopic scissors are available in disposable and nondisposable form. The blades of laparoscopic scissors are shorter than their open surgical counterparts. The configuration of the tip may be useful for selective situations: serrated tips for cutting fascia, hooked tips for cutting sutures, microscissors for spatulating the ureter during a pyeloplasty, and curved tips for dissection. Incision of the tissue is either achieved using an electrosurgical ("hot") or mechanical ("cold") approach.

A **laparoscopic scalpel** is of particular use for incision of the ureter during laparoscopic ureterolithotomy or of the urethra during laparoscopic radical prostatectomy.

For **electrosurgical incision** of tissue a selection of different electrodes is available: needle electrodes (Corson-type) produce fine cuts which are useful in peritoneal incisions, spatula electrodes are utilized in blunt dissection and cutting, hook electrodes (J and L configuration) are of particular value during dissection of vessels, as tissue can be pulled away from delicate structures before activating the cutting current (Figure 8). The thinner the metal tip of the probe, the higher the density of the electrical current and the greater the cutting power.

As with all insulated instruments, certain precautions must be followed during electrosurgery to avoid local or distant transmitted thermal injury. Consequently, the electrosurgical probe should not be activated without having the metal, or non-insulated, part in complete view. The insulation of the electrosurgical instrument should be carefully checked for any damage. The probe, if coagulating current is being used, should not be activated unless it is in direct contact with the tissue to be incised; if cutting current is being used, it is helpful to activate the probe $<1\text{mm}$ from the tissue and then initiate contact. The

surgeon should realize that the energy going through the probe is upwards of 10 fold higher when coagulating current is used as opposed to cutting current. Also, use of the electrosurgical instrument through a metal rather than plastic cannula decreases the chances of inadvertent electrosurgical injury due to capacitive coupling. In this regard, one should never use a metal trocar in conjunction with an outer plastic retaining ring as stray current can no longer be harmlessly dissipated through the metal cannula directly to the surrounding peritrocar abdominal wall. Lastly, with regard to electrosurgical safety, there is one set of instrumentation in which any break in the insulation results in the automatic inactivation of the instrument thereby precluding inadvertent injury to tissues adjacent to the probe (Encision Inc., Boulder, CO).

The laparoscopic surgeon can choose between monopolar and bipolar cutting devices. Hemostasis is most safely achieved by utilizing bipolar devices which require less energy for performance. There is also a decreased likelihood of injury to surrounding tissue as the electrical current is passing only from one jaw to another thereby precluding capacitive coupling. A variation on bipolar electrosurgery, is the LigaSure vessel sealing system (Valleylab Inc., Boulder, CO). The system consists of a 5 mm Maryland-style grasper/dissector or a 10 mm grasping device, with a cutting blade to transect the coagulated vascular structure, and both are connected to a bipolar radiofrequency generator. When the vascular structure is grasped by the instrument, the tissue is evaluated by a feedback-response system which subsequently delivers the optimal energy required to seal the vessel effectively. Due to the high-current and low-voltage output, the vascular structure enclosed by the jaws of the instrument degrades quickly and a protein based seal is created; this mechanism of electrical current delivery to the tissues results in less charring and less collateral thermal damage. Studies have shown favorable occlusive properties during pressure tests when compared to ultrasonic and conventional bipolar coagulation (Kennedy et al, 1999). Vessels up to 7 mm appear to be effectively occluded with this device, and it is ideal for securing the gonadal, ascending lumbar and adrenal veins.

In urologic and general surgery laparoscopy, lasers are not currently being used; they have largely been supplanted by electrosurgical instruments. Only in gynecology is the CO₂ laser used extensively, largely in the treatment of endometriosis. **Lasers (CO₂, KTP, Nd: YAG)** are most frequently used through the working channel of an operating laparoscope. The CO₂ laser provides excellent cutting and vaporization of surface lesions; this laser requires a rigid hand piece and probe. In contrast, the 400 μ m and 600 μ m KTP fibers are flexible, they allow for noncontact cutting and fulguration (KTP). The Nd:YAG laser fibers are also flexible and provide for noncontact fulguration and contact cutting. Fibers with sculpted tips provide more precise cutting. Laser-specific goggles must be worn during all laser-related procedures by all individuals (including the patient) in the operating room.

Ultrasonic technology provides another option for dissection in endoscopic surgery. It provides an especially attractive alternative to monopolar electrosurgery when one is working around particularly delicate tissues or when operating in patients with an implanted pacemaker/cardioverter defibrillator. In

ultrasonic surgery, electrical energy is transformed into mechanical energy by the use of a piezoelectric crystal system. Rapid mechanical vibrations, produced by this system, are capable of creating the following effects on tissue: cavitation, coaptation/coagulation, and cutting (Strate et al, 1999). Currently, there are 2 different forms of ultrasonic technology available for laparoscopic surgery: the ultrasonic cavitational aspirator and the ultrasonically activated scalpel ("harmonic knife"). The **ultrasonic cavitational aspirator** fragments and aspirates tissues with a high water content (e.g. fat cells). Collagen-rich tissues, such as nerves or blood vessels, are largely preserved. Its tip oscillates at 23 kHz and has an excursion from side to side of 200 to 360 μm . Although this technology is helpful in dissecting and identifying vessels, it is not widely used due to its slowness and lack of hemostasis. It has been most extensively used during adrenalectomy in patients with Cushings disease/syndrome to help clear away the abundant fat which surrounds the adrenal gland in these patients (Suzuki et al, 1995). In the **ultrasonically activated scalpel** ("harmonic knife") electrical energy is produced by a power supply generator and transformed into mechanical vibration within a handpiece that contains piezoelectric crystals (Figure 8). Mechanical vibration (frequency from 23.5 to 55.5 kHz) with a tip excursion of 80-200 μm is subsequently transferred to a scissors or hook blade. Multifunctionality (grasping, cutting, dissecting, and coagulation) is provided when a scissors-type tip is utilized. In addition to the absent risk of local thermal damage and tissue charring due to its working temperature of $< 80^\circ\text{C}$, the depth of penetration is limited to the targeted tissue and a 1 mm area on either side of the point of application. This is in marked contrast to monopolar surgery that may cause peripheral tissue damage due to its higher working temperature (i.e. upwards of 100°C) and its greater depth of penetration ($<= 5 \text{ mm}$); even with bipolar instruments, charring of the tissue is a risk (Gossot et al, 1999). Reduced tissue charring may result in a reduced rate of postoperative adhesions. In addition, the harmonic scalpel eliminates other problems associated with monopolar electrosurgery; specifically problems of remote site tissue damage due to capacitive coupling, insulation defects in the instrumentation, or direct coupling are all avoided. Potential disadvantages of the harmonic knife include: slowness to achieve the desired effect and relative high cost of these disposable instruments.

The **Argon Beam Coagulator** (ABC: Birtcher Medical Corporation, Irvine, CA), provides a non-contact form of electrosurgery. Electrical current originating from a monopolar electrosurgical generator is conducted to the tissue via an ionized argon gas stream. The gas stream blows away blood from the tissue resulting in better visualization of the bleeding site and hence, more effective fulguration. Argon is a colorless, odorless, inert gas that clears the body within one respiratory cycle. Holding the hand piece at an oblique 60 degree angle within 1 cm of the surface of the target tissue provides optimal fulguration effects. During argon beam fulguration the sidearm on one of the laparoscopic ports must be opened in order to prevent buildup of excessive intra-abdominal pressures. As argon beam coagulation has its major advantage when hemostasis needs to be achieved over a diffusely bleeding surface, its most practical indication in

laparoscopic urologic surgery is during partial nephrectomy or wedge excision of a small renal tumor, but is also helpful for gaining hemostasis with small liver or splenic lacerations.

Another option to stop parenchymal bleeding during laparoscopic surgery is **application of hemostatic material (Avitene stick)** to the bleeding surface (Kerbl and Clayman, 1994). This makeshift device utilizes a 16 cm, 30F teflon sheath and a 28F Amplatz dilator; the former is filled with 1 gm of microfibrillar collagen hemostatic substance (Avitene, Alcon Inc., Humacao, Puerto Rico). While sealing off the distal opening of the sheath with the surgeon's finger, the sterile strip-sealed butt end of a 28F Amplatz dilator is used to compress Avitene into a plug at the distal tip of the teflon sheath. The teflon sheath is then inserted through a 12 mm port and steered towards the bleeding area; the Avitene plug is ramroded out of the sheath and firmly pressed onto the bleeding parenchymal defect with the Amplatz dilator. This technique has been shown to stop diffuse parenchymal bleeding after a laparoscopic wedge excision of a renal tumor even after repeated previous attempts of achieving hemostasis with an Argon beam coagulator have failed. The Avitene stick is now also commercially available for endoscopic use (Davol Inc., Cranston, RI).

Most recently, fibrin glue (Tisseel, Baxter HC, Glendale, CA) with or without a collagen sheet (i.e. Collagen Sponge, Bard, Glendale, CA, or Helistat, Colla-Tec, Inc. Plainsboro, N.J.) has been utilized to stop parenchymal bleeding after laparoscopic partial nephrectomy. The two components of the fibrin glue are delivered through separate channels of a specially designed elongated catheter (i.e. Duplocath 35 M.I.S., Baxter HC, Glendale, CA) until they combine at the tip of the delivery system thereby creating the glue. This substance is thus both a hemostatic agent and a sealant. Another hemostatic, but nonsealing, compound is gelatin matrix hemostatic sealant (Floseal, Baxter HC, Glendale, CA) which is specially engineered collagen and thrombin which requires the presence of the patient's fibrinogen to create a hemostatic coagulum. Therefore, this product works best in an actively bleeding cavity so the activated fibrin polymer can form a clot around the collagen matrix. However, contrary to its name, it has no ability to seal any nonbleeding tissue such as the collecting system or a small hole in the diaphragm.

4. Instrumentation for suturing and tissue anastomosis

Suturing and knot tying are among the most difficult tasks to master in laparoscopic surgery. A significant amount of practice is needed in order to achieve a sufficient level of proficiency. **Laparoscopic needle holders** have one fixed jaw and one jaw that opens by squeezing the spring-loaded handle of the instrument (Figure 8). Due to the length and narrow shaft of the needle holders, they all have a locking mechanism to secure the needle in the jaw of the needleholder. This is done with a ratchet, spring-loaded, or a Castro-Viejo type mechanism. Some needle holders also possess a valuable feature which allows the jaws to rotate around the main axis, relative to the handle. **Suture introducers** may be used for easier insertion of needle and suture thereby avoiding problems at the flap valve system of the cannulas; however, most

needles can be introduced directly through a 10 mm or 12 mm port. **Knot pushers** are utilized during extracorporeal knot tying techniques. Knot pushers which work independent of the suture material either slide (Clarke-Riech) or cinch (Gazayerli) the knot into place. Integral knot pushers are part of a system that contains a preformed ligature loop. As soon as the loop of the preknotted suture is passed over the tissue to be secured, the knot is delivered and secured around the target tissue with the integral pusher. The suture is then cut and the plastic knot pusher is removed and discarded.

The EndoStitch (US Surgical Corp., Norwalk, CT) device is an innovative disposable 10-mm instrument that facilitates laparoscopic suture placement and knot tying. The suture is secured to the center of a straight needle which has a pointed end on both sides thereby allowing for tissue penetration in either direction. By shuttling the needle back and forth between the jaws of the instrument after each passage through the tissue, it applies a long known principle used in sewing machines. As such, passing the needle through the tissue and regrasping the needle after it has traversed the tissue becomes a simple task, as it is all done by a one-handed squeeze of the handle and a flip of the needle securing lever, respectively. Utilizing this sewing apparatus has had a major impact on decreasing operative times, especially in laparoscopic pyeloplasty.

5. Instrumentation for stapling and clipping

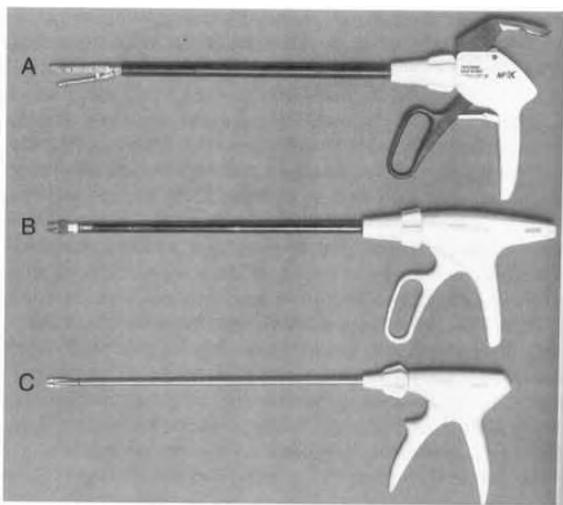
Stapling devices: Various stapling devices are available: manual linear cutting and noncutting, and powered linear cutting and noncutting (Figure 9). The EndoGIA 30 (US Surgical Corp., Norwalk, CT), operated through a 12 mm port, was the first laparoscopic manual linear cutting device. The Endo GIA 30, which requires a 12 mm port and Endo GIA 60, which requires a 15 mm port, deliver two triple staggered rows of staples and simultaneously cut in between the rows. The EndoPath 30 and 60 (Ethicon EndoSurgery Inc., Somerville, N.J.) require a 12 and 18 mm trocar, respectively. The disposable device can be reloaded multiple times during a procedure; each staple load is color-coded depending on the size of the staples: 2.5 mm staples (white cartridges) are preferred for vascular stapling (i.e. renal vein) while 3.8 mm (blue) and 4.8 mm (green) staples are utilized in thicker tissues (i.e. ureter, bowel, bladder). When using these staplers, special attention must be paid to the markers on the cartridge to be certain all of the targeted tissue is properly situated between the markers prior to closing and firing the cartridge.

Several staplers have been developed to achieve end-to-end, end-to-side, and side-to-side anastomoses in various laparoscopic procedures (i.e. colorectal surgery). The Premium Plus CEEA stapler (US Surgical Corp., Norwalk, CT) and the Endopath Curved Intraluminal Stapler (Ethicon, Somerville, N.J.) achieve a circular anastomosis by delivering circular, double staggered staple rows. To prevent stretching or thinning with subsequent leakage and narrowing of the anastomosis the optimal size of the staple cartridge should be evaluated using a disposable sizer. Accordingly, the laparoscopic surgeon can choose among different cartridge sizes (Premium Plus CEEA 21/25/28/31/34 Stapler, or

Endopath Curved Intraluminal 21/25/29/33 Stapler). Linear noncutting staplers either deliver three or four staple rows in 30 or 60 mm lengths. They require less enclosure of tissue during reapproximation and are thus used to close an enterotomy after a side-to-side bowel anastomosis.

Clipping devices: Disposable and nondisposable clip appliers are available from different manufacturers (Figure 9). Generally, they contain occlusive clips ranging in sizes from 6 to 11 mm; they require either 10 or 12 mm laparoscopic ports. Recently, a 5 mm, disposable clip applier (Ligaclip Allport,

Figure 9 Laparoscopic stapler (A) and clip applier: 10mm (B) and 5mm (C).



Ethicon EndoSurgery Inc., Somerville, N.J.) has also become available using 9 mm clips. Disposable clip appliers possess a rotatable shaft and multifire, self-reloading features, whereas nondisposable instruments have to be inserted individually for each clip to be deployed at the site of surgery and usually don't have a rotating shaft. Recently, a right angle clip applier has become available which fits through a 10 mm trocar; the right angle deployment of the 8 mm titanium (AcuClip, U.S. Surgical Corp., Norwalk, CT) clip is ideal for securing the renal artery and smaller veins (e.g. gonadal vein) during a laparoscopic nephrectomy. In an effort to decrease costs while facilitating laparoscopic procedures, a multifire clip applier has become available in which the applier itself is nondisposable and a disposable cartridge of clips is loaded into it for delivery (Aesculap, San Francisco, CA; Applied Medical, Rancho Santa Margarita, CA). Other types of clips include the spring-loaded clip (Surgicon, Stratford, CT) and the plastic self locking clip (Weck, Research Triangle Park, NC) for secure vessel occlusion. With these devices only one clip needs to be used to secure the vessel; although most surgeons still prefer to use two clips on the "stay" side.

Electrocoagulation must be avoided in the vicinity of clips placed for occlusion of vessels to prevent conductive tissue necrosis and subsequent clip dislocation. To ensure reliable function the closed ends of the occlusive clips need to be seen extending beyond the occluded vessel slightly and should be placed perpendicular to the longitudinal axis of the vessel.

Biting clips (reusable and disposable) were primarily developed to tack Marlex mesh to the inner abdominal wall as part of a laparoscopic hernia repair. Further indications for these clips which close in a rectangular or in a "B" configuration include reconstruction of peritoneal surfaces after ureterolysis, fixation of vesicourethral slings to Cooper's ligament, and extraperitoneal laparoscopic urethropexy using Marlex mesh (Dickson et al, 1992; Moran et al, 1991; Blander et al, 1999). A specialized circular tacking clip is also available for reconstructive purposes (Origin Tacker System, U.S. Surgical Corp., Norwalk, CT). This spring like clip secures two tissue surfaces to one another by spiraling through them.

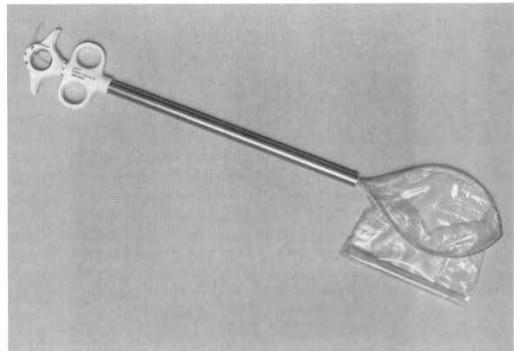
LapraTy clips (Ethicon EndoSurgery Inc., Somerville, NJ) are made of absorbable polydioxanone; they can be secured to the end of a single strand of 2-0, 3-0 or 4-0 coated Vicryl); as such, the clip acts as a knot, thereby precluding time consuming intracorporeal laparoscopic knot-tying. They provide secure anchoring of sutures for up to 14 days in low- to mid-tension environments. When used to secure a single suture, the suture must have a pretied loop on its end; the needle is passed through the tissues to be secured and then passed through the pretied loop. Next, the suture is pulled taut thereby tightening its hold on the encircled tissue; the LapraTy clip is then affixed to the suture material just as it exits the loop. For a running suture, the LapraTy clip can be used both to anchor the end of the suture and secure the suture upon completion of the run; this combination has worked very well during pyeloplasties with the EndoStitch.

6. Instrumentation for specimen entrapment

A variety of organ entrapment and retrieval systems is available. Depending on the size of the tissue and whether in situ morcellation or intact organ retrieval is planned, the laparoscopic surgeon is able to choose among different sized sacks, materials and designs. Various studies have been conducted to test organ retrieval bags for permeability to tumor cells and bacteria before and after morcellation, as well as stability during morcellation and resistance to tear forces (Urban et al, 1993; Rassweiler et al, 1998). The originally designed LapSac (Cook Urological, Spencer, IN) which is made of nylon with a polyurethane inner coating and polypropylene drawstring, is the least susceptible to perforation. Deployment of the LapSac and subsequent organ entrapment remain a tedious endeavor. However, the maneuver to open the LapSac in the abdominal cavity can be simplified by twice threading a nitinol guide wire through every other one of the holes at the neck of the sack through which the closure string passes. The LapSac is rolled up and introduced through a port site and the port replaced leaving the ends of the guide wire on the outside of the abdomen. The nitinol guidewire allows the neck of the LapSac to spring widely open once inside the abdomen, thereby facilitating the specimen entrapment.(Sundaram et al, 2002) Other sacks offer marked advantages when the sole goal is organ entrapment and intact removal, rather than morcellation. These sacks have spring-wires which when activated by the surgeon, deploy the bag after its introduction into the abdomen; this facilitates tissue entrapment as the opening metal band stabilizes the opened sack, thereby allowing the

surgeon to literally scoop the specimen into the sack [i.e. LapBag (Bard-Angiomed, Salt Lake City, UT), ExtractionBag (Karl Storz, Culver City, CA), Endo-Catch (US Surgical, Norwalk, CT), Endopouch (Ethicon, Cincinnati, OH)] (Figure 10).

Figure 10 Organ retrieval bag; not suitable for morcellation.



7. Instrumentation for morcellation

Various techniques of tissue morcellation have been used in laparoscopic surgery. The simplest methods of fragmentation of tissue within the entrapment sack are the use of the index finger, ring forceps or Kelly forceps. The first mechanical morcellation devices worked by punching out pieces of tissue (i.e. serrated-edge macro-morcellator S.E.M.M.). These were designed for removing relatively small amounts of tissue. The advent of laparoscopic nephrectomy resulted in the development of a foot activated, aspirating, electrical morcellator for tissue fragmentation and evacuation (Cook Urological, Spencer, IN) (Clayman et al, 1992); however, this device is no longer available on the market. Recently, a second electrical morcellator has been developed. The Steiner morcellator consists of a hollow, cutting device and an electrical engine. Strong grasping forceps are passed through the hollow center of the device; the tissue is pulled into the opening of the rotating, cutting barrel and the resulting core of tissue is delivered out the backend of the morcellator. Experimental studies have shown that morcellation time with the Steiner instrument (Storz Endoscopy, Culver City, CA) is quick. Furthermore, due to the larger size of the specimen retrieved via the Steiner morcellator, histopathologic evaluation is easier. However, the Steiner morcellator, at present, cannot be used for malignant tissue as there is no entrapment system presently available that can be used in conjunction with this morcellator. (Landman et al, 2000)

8. Instrumentation for aspiration and irrigation

Available either as a disposable or nondisposable device, a combination of aspiration and irrigation in one instrument is most practical. The aspirator, which is connected to a suction system, consists of a 5- or 10-mm metal tube with suction being controlled by either a one-way stopcock or a spring-controlled trumpet valve. The irrigation channel is also operated either by a one-way stopcock or a trumpet valve. The irrigation fluid is pressurized within a range of 250 to 700 mmHg to allow for effective delivery of the irrigant and flushing of any bleeding site to allow for accurate hemostasis. Usually, saline or lactated Ringer's solution is used as the irrigation fluid. Heparin (5000 units/liter) may be added to prevent blood clots from forming, should there be any intraoperative

bleeding. Furthermore, a broad spectrum antibiotic (e.g. 1 gm cefazolin/liter) may be added to the irrigant at the end of the procedure, if one desires to further wash the surgical site just prior to exiting the abdomen.

9. Instrumentation for retraction

Retractors greatly facilitate laparoscopic surgery. They are helpful to expose the area of surgical interest by holding away tissue and organs (i.e. liver, spleen, bowel). Sometimes, they also facilitate vascular dissection, by putting tissue and/or organs closely associated with the vascular structures on stretch. A large variety of retractors with different features is available. The simplest retractor is a metal bar with an atraumatic tip or with a curved saddle shape (i.e. "eyelid" retractor); the latter is helpful for retracting a vessel during a lymph node dissection. However, the most useful retractors are the expanding types: fan retractors with three or four atraumatic fingerlike extensions, fan retractors with V-hinge joints, balloon retractors, and kite-style instruments (Brooks, 1993). The last are PEER retractors (J. Jamner, Hawthorne, NY) which have proven to be of high practical value during laparoscopic nephrectomy, specifically for dissection of the medial tissue planes and the renal hilum. The 5 mm version provides a 2 cm retracting area, whereas the 10 mm instrument doubles the area of direct retraction to 4 cm (Figure 11).

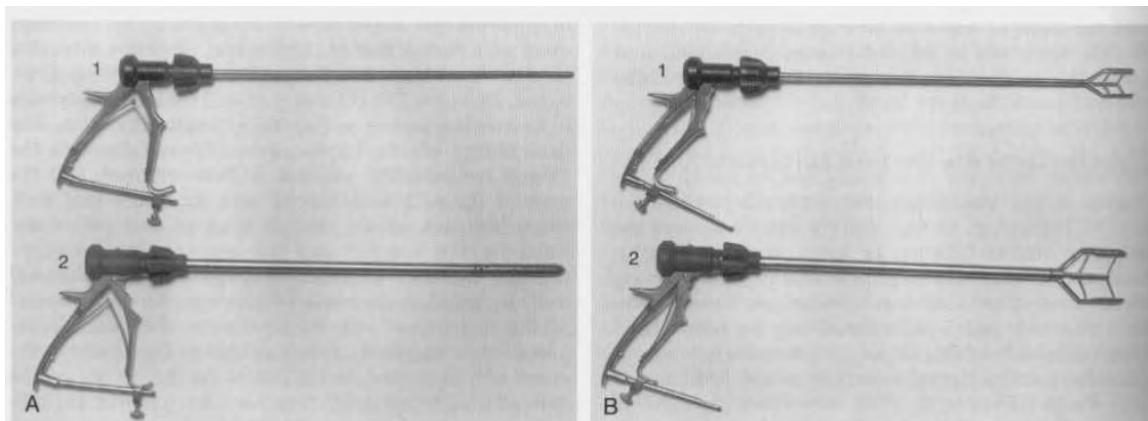


Figure 11 PEER retractor. A, Closed 5mm (1) and 10mm (2). B, Open: 5mm (1) and 10mm (2). (From Walsh PC, Retik AB, et al (eds): Campbell's Urology. Philadelphia, Saunders, 2002)

Another type of retractor is malleable and thus can be shaped to the needs of the surgeon. The diamond flex (i.e. angled triangular retractor; Snowden Pincer) is composed of multiple links giving it almost a goose-neck appearance. It is placed in the abdomen "straight" and loose; by turning the dial on the top of the retractor the links are caused to assume a preformed triangle-shaped retracting surface that is literally 8 cm in width. Given the absence of any metallic projections on this retractor (e.g. the legs on the PEER retractor or fingers of the fan retractor) and its broad atraumatic surface, it is ideal for retracting the liver.

Retraction of tube-like structures (i.e. vessels and ureter) can also be achieved by placing a suture, vessel loop or an umbilical tape around the tissue

with/without securing it with a 9-mm clip and applying retraction either with a grasper inside the abdomen or by pulling the ends of the retraction loop out of the abdomen through a small stab-incision using a Carter Thomason device. The retraction loop can then be secured under slight tension on the surface of the abdomen with a small hemostat clamp.

External mechanical devices such as the Endoholder (Codman, Raynham, MA) can be used to keep grasping forceps or locking retractors in place. This device is usually mounted on the side of the table opposite the surgeon; the malleable free arm of it is then affixed to the shaft of a grasping forceps or laparoscopic retractor. When the surgeon has appropriately placed the retractor, the malleable arm of the external mechanical device is locked in place onto the shaft of the retractor; next, the arm of the Endoholder is tightened, thereby providing reliable continued, traction. In most cases, this device takes the place of the second surgical assistant.

10. Hand-assisted laparoscopy

This concept was originally developed as a supportive technique to laparoscopic splenectomy (Kusminsky, 1995). Subsequently, hand-assisted laparoscopy was also embraced by urologic surgeons. Recent developments in commercially available devices [e.g. Pneumosleeve (Dexterity, Inc., Blue Bell, PA), Intromit (Applied Medical Resources, Laguna Hills, CA), HandPort (Smith and Nephew, Andover, MA) and Omniport (Advanced Surgical Concepts, Bray Ireland)] have further spurred this approach. Recently introduced HAL devices [e.g. Gelpoint (Applied Medical Resources, Laguna Hills, CA), LapDisc (Ethicon Endosurgery, Cincinnati, Ohio), Omniport (Advanced Surgical Concepts, Bray Ireland)] are simplified in application to the abdominal wall and do not require a special sleeve for the surgeon's arm facilitating ambidextrous utilization of the access site (Figure 12).



Figure 12 Components of the hand-assisted laparoscopy device, the GelPort; wound protector, external abdominal wall ring, hand access port (Applied Medical Resources, Rancho Santa Margarita, CA)

The first report on the use of the PneumoSleeve for performing a hand-assisted laparoscopic nephrectomy was published in 1997 (Nakada et al, 1997). Since then, hand-assisted techniques have been successfully applied to a variety of other laparoscopic procedures among them nephroureterectomy, partial nephrectomy, colectomy, Roux-en-Y gastric bypass, complex hysterectomy, distal pancreatectomy, rectopexy and fundoplication.

Recent studies using well under 50 patients per treatment arm, have shown no statistically significant differences in the areas of length of hospital stay, return to normal activities and postoperative pain when compared to

standard laparoscopic nephrectomy (Wolf et al, 1998). However, there is a trend toward less problems in each of these areas with a pure laparoscopic approach (Dunn et al, 2000).

Proponents of this approach argue that hand-assisted procedures, while utilizing only a 7 to 8 cm incision, offer many advantages which have been otherwise the mainstays of open large-incisional surgery: availability of tactile sensation, gentle manual retraction of delicate and fragile organs (i.e. spleen and liver), rapid development of natural tissue planes, fast digital identification and easier dissection of major blood vessels, and effective means of achieving quick hemostasis in the event of sudden hemorrhage. By having one hand in the surgical area, while carrying out the procedure using exclusively laparoscopic instruments, the potential advantages of open incisional surgery are combined with the favorable characteristics of laparoscopic surgery, such as decreased operative time, shortened hospital stay, and fast convalescence. However, hand-assisted techniques require a larger incision (7-8 cm) than procedures purely performed by laparoscopic means. Therefore, the optimal benefit is encountered when this technique is selectively applied: such as for those procedures with technically difficult situations (e.g. laparoscopic nephrectomy for xanthogranulomatous pyelonephritis, laparoscopic nephrectomy for autosomal dominant polycystic kidney disease) and procedures in which intact organ removal is planned (e.g. laparoscopic donor nephrectomy, laparoscopic radical nephroureterectomy).

11. Exiting The Abdomen

Port removal and fascial closure are key elements of the procedure which if not performed in a step by step organized fashion can result in major, possibly fatal, complications. Herniation, possible bowel incarceration, and postoperative hemorrhage are the results of a poorly performed or haphazard closure.

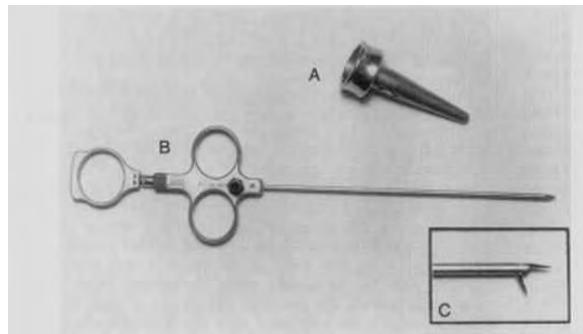
Before port removal is initiated, the operative site and the intraabdominal entry sites of the cannulas need to be carefully inspected. With the intraabdominal pressure lowered to 5 mm Hg, any venous bleeding should become detectable. After achieving perfect hemostasis, the surgical site is irrigated with the option of leaving 500 to 1000 ml of irrigation fluid behind, which contains 1 g Cefazolin/liter and 5000 U/liter of heparin. Whether this maneuver truly results in a lower incidence of postoperative adhesions or less infection is undetermined. To avoid any possible herniation of intraabdominal contents into the previous port sites, removal of all laparoscopic ports must be undertaken strictly under visual control. To this end, each \geq 10 mm sheath is removed under optical control via a 5 mm endoscope passed through a 5 mm port. For \geq 10 mm ports placed via a bladed trocar, the fascia at the entry site is secured with a 0-Vicryl. This suture is not tied at the time of placement, but instead a 10mm plastic introducer rod is passed back into the abdominal cavity through the port site incision. The 10 mm cannula is then slid over the 10mm plastic introducer and the plastic introducer is removed. As such, the ports, as they are each in turn replaced, can continue to be used for the passage of the 10 mm laparoscope and passage of a grasping forceps to facilitate the closure of each \geq 10 mm port site. Accordingly, all fascial sutures are placed under direct

endoscopic control as the 10 mm laparoscope is moved from port to port in order to visualize the placement of each suture. After all fascial sutures have been placed, then using a 5 mm laparoscope via a 5 mm port, each of the > 10 mm ports are removed and the fascial suture secured. The final 5 mm port is removed with the endoscope in place in order to assess for any bleeding along the tract. In this manner, each port is visually assessed for any bleeding at 5 mm Hg thereby precluding the possibility of removing a port and missing an injured vessel. After removal of all ports, the CO₂ is allowed to pass out passively through the 5 mm port entry sites. In pediatric laparoscopy all ports \geq 5mm are closed with a fascial and peritoneal suture closure.

A variety of **instruments for closure of port sites** exist. The **simplest method** is retracting the skin with Sinn retractors, grasping the fascia with Kocher clamps and suturing it with absorbable 0 suture. Exposure of fascial edges, especially **in obese patients** is difficult. Fortunately, several **disposable and nondisposable devices for complete en bloc closure of fascia, muscle and peritoneum** under direct vision have been developed (Elashry et al, 1996). These work well in patients of all sizes. These devices include the following: Carter-Thomason device (Inlet Medical, Eden Prairie, MN), Maciol suture needle set (Core Dynamics, Jacksonville, FL), eXit disposable puncture closure device (Progressive Medical, St. Louis, MO), Endo Close suture carrier (US Surgical, Norwalk, CT), and Surgical Instrument ligature (TSI, San Juan, Puerto Rico). Among these devices, one of the most useful and reliable has been the Carter-Thomason closure device.

The **disposable Carter-Thomason needlepoint suture passer** (Inlet Medical, Eden Prairie, MN) consists of a 10 mm metal cone that has 2 integrated hollow, angled cylindrical passages located 180 degrees opposite to each other (Figure 13). With the sharp needle-point, single action grasper the 0-Vicryl suture is inserted through one of the cylinders in the cone, thereby traversing muscle, fascia and peritoneal layers in an ever widening angle; the intraperitoneal end of the suture is grasped with a 5 mm grasper via one of the other ports. The needle point grasper is reintroduced through the other cylinder of the metal cone; the intraperitoneal end of the suture is grasped by the needle point grasper and pulled out of the abdomen. The metal cone is slid off of both ends of the suture. Subsequently, closure of the fascia, muscle layer and peritoneum is accomplished by tying the suture. The disposable Carter-Thomason needlepoint device is helpful not only for wound closure but also can be used as a fifth port during a nephrectomy to help hold a LapSac open or to encircle the ureter with a vessel loop through a small stab incision.

Figure 13 Disposable Carter-Thomason device. Plastic cone (A); needle-point, single-action grasper (B); and tip of grasper in open condition (C). (From Walsh PC, Retik AB, et al (eds): Campbell's Urology. Philadelphia, Saunders, 2002)



A far simpler, less expensive homemade solution is available to all surgeons for closing ports in a large patient. The **angiocatheter technique** applies the aforescribed principles. A 14-gauge sheathed needle is passed alongside the ≥ 10 mm port through the abdominal layers. After removal of the needle, a 0-Vicryl suture is inserted through the angiocatheter sheath until it is deep inside the peritoneal cavity. After removal of the sheath the same maneuver is repeated on the opposite side, but this time a 30-inch long 0-Prolene suture folded in half is passed into the peritoneal cavity through the sheath to act as a retrieving loop. Now a 5 mm grasper passed through another port, is passed through the loop of 0-Prolene and used to grasp the end of the 0-Vicryl suture. The 0-Vicryl suture is pulled through the Prolene loop and released. Now by pulling the Prolene loop upward through the angiocatheter sheath, the entrapped 0-Vicryl suture is retrieved from the abdomen. After removal of the angiocatheter sheath, the two ends of the suture can be tied.

For ≥ 10 mm ports placed via a nonbladed trocar, no fascial suture is needed provided the port has been placed off of the midline. For midline ≥ 10 mm ports placed via a nonbladed trocar, closure is dependent upon the surgeon's judgment. If the opening in the midline fascia has not been stretched, as determined by the surgeon's finger, then the fascia need not be closed. (Shalhav et al, 2002) However, many surgeons still prefer to close even nonbladed, larger midline port sites with a fascial suture. (Lowry et al, 2003)

Using animal models, the eXit disposable puncture closure and the Carter-Thomason needlepoint suture passer were found to have some advantages over other devices (Elashry et al, 1996). The nondisposable Carter-Thomason needlepoint device is helpful not only for wound closure but also can be used as a fifth port during a nephrectomy to help hold a LapSac open or to encircle the ureter with a vessel loop through a small stab incision.

All 5 mm sheaths are removed under optical control at 5 mm Hg. In adults the fascia of the 5 mm port entry sites is not sewn closed; however, in children, these port sites require closure with a single absorbable suture.

The skin of all ≥ 10 mm port sites is closed with a subcuticular 4-0 absorbable suture. Adhesive strips are applied to all port sites to close (i.e. < 10 mm incisions) or to further approximate (i.e. ≥ 10 mm incisions) the skin.

4. Pneumoperitoneum Effects

The rapidly expanding number of newly developed laparoscopic procedures in operative urology has resulted in an increasing need for urologists as well as anesthesiologists to familiarize themselves with both the physiology and potential complications of the pneumoperitoneum. This is especially important now that laparoscopic urology has moved on to even more complicated ablative and reconstructive surgery, requiring prolonged pneumoperitoneum.

A. Choice of gas for establishing a pneumoperitoneum:

Carbon dioxide (CO_2) is the insufflant most commonly used for laparoscopic surgery. Due to its properties (colorless, noncombustible and inexpensive) it is favored by most laparoscopists. Prolonged postoperative distention of the abdomen does not occur, as CO_2 is quickly absorbed (Wolf and Stoller, 1994). It is highly soluble in water and easily diffuses in body tissues. Due to its high diffusion coefficient, when compared to oxygen and other respiratory gases, it readily moves out of the peritoneal cavity following a high diffusion gradient caused by the difference of concentration of CO_2 between the intraperitoneal space and surrounding compartments (i.e. blood). However, the characteristic of rapid absorption, which lessens the chance of a CO_2 gas embolus, may also lead to potential problems (i.e. hypercapnia, hypercarbia and associated cardiac arrhythmias). In particular, patients with chronic obstructive lung disease may not be able to compensate for the absorbed CO_2 by increased ventilation; this may result in dangerously elevated levels of CO_2 in these patients. CO_2 also stimulates the sympathetic nervous system, which results in an increase in: heart rate, cardiac contractility, and vascular resistance. Lastly, CO_2 is also stored in various body compartments (i.e. viscera, bones and muscles). Following prolonged laparoscopic procedures, it may take hours before the patient has eliminated the extra CO_2 which has accumulated in these storage areas; again, this is more so the case in the patient with any pulmonary disorders. Therefore, all patients, and in particular those with pulmonary disease, must be closely monitored for several hours following lengthy laparoscopic procedures.

Alternative insufflating gases include **nitrous oxide** which is less irritating to the peritoneum and causes less acid-base changes and cardiovascular adverse effects (i.e. arrhythmias) when compared to CO_2 (Minoli et al, 1982). However, some studies have shown that nitrous oxide insufflation reduces cardiac output and increases mean arterial pressure, heart rate, and central venous pressure. As nitrous oxide supports combustion, it can only be used during laparoscopic procedures that do not involve the use of electrosurgical instruments.

Helium is an inert and noncombustible insufflant. Initial studies using Helium as an insufflant performed in various animal models showed favorable effects on arterial pCO_2 and pH with no evidence of hypercarbia. These results were corroborated by clinical studies (Neuberger et al 1994). As such, helium is particularly useful in the patient with pulmonary disease in whom hypercarbia would be poorly tolerated. Likewise, if hypercarbia develops during a

laparoscopic procedure with CO₂, rather than aborting the procedure or converting to an open approach, the surgeon can change the insufflant to helium and usually salvage the case. There is also evidence that the use of helium may cause a decrease of tumor-cell growth and inflammatory reactions within the peritoneal cavity (Jacobi et al, 1997). Most recently, it has been demonstrated that helium insufflation can be used for laparoscopic procedures (i.e. cholecystectomy, appendectomy, and hernia repair) performed under local and regional anesthesia in high-risk patients not only because of its favorable metabolic features, but also due to its lack of peritoneal irritation and its association with less postoperative pain (Crabtree and Fishman, 1999). However, laparoscopists have to bear in mind that helium may be associated with a higher risk of gas embolism due to its lower blood solubility. If helium is going to be used, it is advised to obtain the pneumoperitoneum initially with CO₂ and then change to helium, thereby lowering the chances of a helium gas embolus. Also helium is significantly more expensive than nitrous oxide or CO₂. Furthermore, it should not be used when extraperitoneal insufflation is needed, due to an increased risk of pneumothorax.

There are other insufflants (e.g. **room air, oxygen**) which have been used to establish a pneumoperitoneum in the past. However, potential serious side effects have terminated their clinical applicability (i.e. air embolus, intraabdominal explosion and combustion with oxygen and room air). Other options for insufflants include some of the other “noble gases” (i.e. **xenon, argon, and krypton**) which are inert and nonflammable; however, their widespread clinical use has been largely precluded due to their high costs.

B. Cardiovascular effects of pneumoperitoneum

Animal studies have shown, that the effects of the pneumoperitoneum on **venous return** depend on atrial pressures which in turn are a reflection of the hydration state of the subject (Kashtan et al, 1981). If atrial pressures are low (normo-and hypo-volemic state), then during a pneumoperitoneum of up to 20 mm Hg, venous return is reduced due to increased compression of the vena cava from the pneumoperitoneum. If atrial pressures are high (hypervolemic state), the vena cava resists elevated intraabdominal pressure and venous return is actually enhanced. However, these principles only apply to an intraabdominal pressure of up to 20 mmHg. With further increasing pneumoperitoneum pressures, especially at 40 mmHg and above, capacitance vessels are collapsed, vascular resistance increases, blood flow decreases markedly, and venous return is significantly reduced. Lower extremity venous return is also reduced by elevated intraabdominal pressures. Reduced venous blood flow in lower extremities could potentially facilitate deep vein thrombosis; however, clinically this remains a rare complication of laparoscopy. As a result of a variety of clinical trials, intraabdominal pressures during laparoscopy should not be allowed to exceed 20 mmHg over extended periods of time or 25 mm Hg for brief periods (i.e. 10 - 15 minutes).

Cardiac arrhythmias, including tachycardia and ventricular extrasystoles may be seen as a result of hypercapnia. Peritoneal irritation may lead to vagal

stimulation and subsequently to bradyarrhythmias. Also, dysrhythmias can serve as clinical warning signs for the occurrence of pneumothorax, hypoxia and gas embolism (Wolf and Stoller, 1994).

As previously noted, intravenous pressures may actually rise during low intraabdominal pressures. In addition, increasing intraabdominal pressures may artificially elevate central venous pressure readings due to an increase in intrathoracic pressure. Therefore it is important for the anesthetist to not rely on central venous pressure readings for any clinical decision making. If information regarding vascular volume and central venous pressure is needed, a Swan-Ganz catheter should be placed.

C. Respiratory effects of pneumoperitoneum

Due to the increased intraabdominal pressure diaphragmatic motion is limited. Pulmonary dead space remains unchanged, but functional reserve capacity decreases (Wolf and Stoller, 1994). The average peak airway pressure needed to keep up a constant tidal volume increases parallel to the increasing intraabdominal pressure.

While usually not of great clinical importance in a healthy patient population, it is advisable to utilize positive end expiratory pressure techniques when patients with lung disease undergo general anesthesia for a laparoscopic procedure (Wolf and Stoller, 1994).

The head-down position has an adverse effect on respiration. It elevates the diaphragm and decreases vital capacity. It can also lead to a dislocation of the endotracheal tube that in turn may cause right mainstem bronchus intubation. Although of little clinical significance in healthy patients, the head down position may cause pulmonary edema in patients with increased left-sided heart pressures.

D. Renal and other visceral effects of pneumoperitoneum

Increased intraabdominal pressure was found to be associated with a significant decrease in urinary output. A number of investigators, with the oldest study dating back to 1923, have observed **oliguria** and **anuria** associated with an ongoing increase in intrabdominal pressure (Thorington and Schmidt, 1923; McDougall et al, 1996). Decreased renal vein blood flow and direct renal parenchymal compression, rather than marked hormonal changes or ureteral compression, have been shown to be the likely reasons for the oliguric state (McDougall et al, 1996). Neither application of dopamine nor insertion of ureteral catheters were able to improve oliguria due to elevated intraabdominal pressure greater than 20mmHg. These changes occurred regardless of intraperitoneal or extraperitoneal insufflation. These experimental findings in the animal situation have been corroborated in the clinical setting (Chang et al, 1994). Whether antidiuretic hormone or plasma arginine vasopressin, both of which have been measured at increased levels by some investigators, play a major role in oliguria during clinical laparoscopic procedures remains unclear (Solis Herruzo et al, 1989). In general, if one desires to avoid a profound oliguric state during a laparoscopic procedure, a pressure of 10 mm Hg or less is recommended. One

group of researchers have also suggested that intra-operative administration of dopamine at 2mcg/kg/min will protect against the oliguric effect of the pneumoperitoneum. (Perez et al, 2002) In the transplant patients, despite findings in the animal studies, with 1/2gm/kg body weight of mannitol and lasix, urine output may be maintained at > 100 cc/hour despite intra-abdominal pressures of 10 – 15 mmHg.

Decreased blood flow during laparoscopic procedures was not only found in the kidney, but also in **mesenteric vessels** and other organs (i.e. liver, pancreas, stomach, spleen, small and large intestines) (Caldwell and Ricotta, 1987). This may rarely lead to mesenteric thrombosis with catastrophic results. This complication may take days to develop (Schorr, 1998).

Open, incisional abdominal surgery usually results in some postoperative impairment of gastric and intestinal emptying due to intestinal paralysis ("physiologic ileus"). Interestingly, clinical observation and studies undertaken during laparoscopic and open surgical cholecystectomy have shown that laparoscopic surgery causes less significant disturbances of the gastrointestinal motility pattern, therefore resulting in no or less postoperative physiological ileus as compared to open surgery (Halevy et al, 1994). The exact mechanisms responsible for this difference have yet to be defined. Also, despite the increased intraabdominal pressures associated with laparoscopy, there has been no increased incidence of gastroesophageal reflux and regurgitation in patients undergoing laparoscopic procedures.

The pneumoperitoneum may also have an effect on the **metabolic acid-base** system. Animal and human studies have demonstrated that prolonged laparoscopic procedures may result in hypercarbia and respiratory acidosis. As there is no increase in ventilatory dead space during laparoscopy, the resulting respiratory acidosis has been attributed to transperitoneal absorption of CO₂ during establishment and maintenance of the pneumoperitoneum (Leighton, 1993). While the resulting mild respiratory acidosis does not adversely effect otherwise normal patients and can be corrected by increasing the minute ventilation, increased absorption of CO₂ can become dangerous in patients with chronic obstructive lung disease (COPD) due to their impaired ability to eliminate pulmonary CO₂. To ensure proper monitoring of acid-base status, intermittent arterial blood gas sampling should be performed in patients with COPD or during any laparoscopic procedure which requires over 1 hour of carbon dioxide insufflation.

E. Hemodynamic effects

Several animal and human studies have examined hemodynamic changes due to **different surgical positions**. In the supine position, cardiac output remains unchanged or decreases when intraabdominal pressures are \leq 15 mm Hg, while mean arterial pressure and systemic vascular resistance increases (Pearle, 1996). If pneumoperitoneum pressures are increased above 20 mm Hg, cardiac output is reduced due to decreasing venous return.

Changes in patient position have a marked impact on hemodynamic parameters. Specifically, in the head-up position, the heart rate increases, mean

arterial pressure decreases, systemic vascular resistance increases and cardiac output decreases; in contrast, in the head-down position, heart rate drops, mean arterial pressure rises, systemic vascular resistance falls, and cardiac output increases. These results show that the head-down position is favorable for the laparoscopy patient due to higher cardiac output caused by increased venous return. However, this beneficial effect is completely negated if the pneumoperitoneum pressure is increased to 30 - 40 mm Hg; at pressures this high, the concomitant decrease in venous return results in a decrease in cardiac output.

Within a pressure range of 5 to 20 mm Hg, CO₂, there is a stimulatory effect of the **hypercarbia** on the cardiovascular system: decreased peripheral vascular resistance, increased heart rate and enhanced contractility of the myocardium. However, if intraabdominal pressures increase and get closer to 40 mm Hg, regardless of the insufflant, there is a subsequent decrease in venous return and cardiac output. The CO₂ induced favorable hemodynamic effects seen within a pressure range of up to 20 mm Hg are not present when inert insufflants (e.g. helium) are used (Pearle, 1996).

Clinical studies have shown, that **mean arterial pressure (MAP)** decreases after the induction of general anesthesia, with further decreases occurring if the patient is placed in a head-up position (Joris et al, 1993). These changes in MAP parallel changes in cardiac output. After peritoneal insufflation, MAP and systemic vascular resistance increase; as such, the cardiac output remains the same or decreases slightly. The increase in systemic vascular resistance may be attributed to mechanical factors which increase the cardiac afterload (increased venous resistance and compression of the abdominal aorta) as well as to increased sympathetic activity due to the elevated p CO₂. MAP also increases in patients positioned head-down with intraabdominal CO₂ pressures up to 20 mm Hg; this is probably due to increased venous return and increased cardiac output, despite a drop in heart rate.

F. Hormonal and metabolic effects during laparoscopic surgery

Similar to other surgical procedures several hormones (i.e. b-endorphin, cortisol, prolactin, epinephrine, norepinephrine, and dopamine) have been noted to increase during laparoscopic surgery as a response to tissue manipulation, intraoperative trauma, and postoperative pain (Cooper et al, 1982). The clinical significance of increased serum arginine vasopressin levels seen in open surgery and in response to intraperitoneal insufflation during laparoscopy remains unexplained (Solis Herruzo et al, 1989).

Several adverse metabolic changes observed during open cholecystectomy are less pronounced with laparoscopic cholecystectomy: a. less postoperative plasma glucose elevation, b. less decrease in insulin sensitivity and c. reduced hepatic stress response. In addition, conventional open surgery results in a number of other, potentially adverse, reactions: muscle proteolysis, increased intestinal mucosal protein synthesis, and increased hepatic protein synthesis (Fischer, 1995).

One important feature of the catabolic response is a complex intraorgan shift of nitrogen; this reaction has been best characterized in the liver. The conversion of amino acids to urea by the liver is much higher after open incisional cholecystectomy than it is following laparoscopic cholecystectomy; hence the catabolic reaction of the body is decreased with a laparoscopic versus an open, incisional approach (Fischer, 1995). Indeed, in the laparoscopic patient, the reduced postoperative hepatic catabolic stress, associated with a reduced tissue loss of amino-nitrogen may in some way be responsible for more the rapid convalescence which is a hallmark of laparoscopy in general. Lastly, catabolic responses in the form of released cytokines and opioids due to augmented neurohumeral stimuli resulting from incisional tissue trauma may also be lessened with a laparoscopic approach (Fischer, 1995).

G. Immunologic effects of laparoscopic surgery

A number of animal and clinical studies measuring a wide spectrum of inflammatory response mediators (i.e. C-reactive protein, interleukin 6) or other markers of cellular immune functions (i.e. pan-T cells CD3, T helper cells-CD4, suppressor cells-CD8, and natural killer cells-CD16, delayed-type hypersensitivity skin tests, and serial phytohemagglutinin-induced T-cell proliferation) have suggested that laparoscopic procedures generally result in less immunosuppression than their open surgical counterparts (Trokel et al, 1994). This may also play a role in hastening convalescence after laparoscopic procedures. Some data have also suggested that the CO₂ pneumoperitoneum in and of itself, as opposed to exposure of tissues to room air, results in a more favorable immunologic state. Also, there is experimental evidence that less tumor cell growth occurs after laparoscopic procedures than after open procedures (Bouvy et al, 1997). While these data are intriguing, further well-designed prospectively randomized clinical studies are needed to compare the immunologic responses after laparoscopic versus open surgical procedures for urologic cancer. Whether a decrease in inflammatory response mediators and improved postlaparoscopic immune status will translate into a better long-term prognosis for patients with urologic cancers remains to be determined.

H. Choice of pneumoperitoneum pressure

Overall the most commonly selected pressure for performing laparoscopy is 15 mm Hg. However, McDougall and colleagues have shown a marked reduction in oliguria even when working at 10 mm Hg. In contrast Kavoussi prefers a pressure of 20 mm Hg noting increased insufflant filling volume of 22% and possibly less venous bleeding during the procedure (Adams et al, 1999). However, McDougall noted, despite the increased volume, there was only a very small increase in abdominal girth at higher pressures. Other investigators have shown an increase in postoperative pain when working at intra-abdominal pressures of 20 mmHg. Again the consensus remains to work at 15 mm Hg or even at 10 mm Hg if one is concerned about oliguria during the procedure.

Various cardiovascular, renal and respiratory effects seen during different intraabdominal pressures are summarized in table 2. It is of note that the

changes in these physiologic parameters at different levels of pressure may be significantly impacted (i.e. overridden or reversed) due to the health of the individual patient (e.g. pulmonary disease) and changes in the patient's position.

Table 2.

Pressure Effects: 5, 10, 20, and 40 mm Hg

Effects	5mm Hg	10 mm Hg	20 mm Hg	40 mm Hg
Cardiovascular				
Heart Rate	↑	↑	↑	↑
Mean arterial pressure	↑	↑	↑	↓
Systemic vascular resistance	↑	↑	↑	↑
Venous return	→ ↓	↓↑	↓↑	↓
Cardiac output	→ ↓	→ ↑	→ ↓	↓
Renal				
Glomerular filtration rate	→	↓	↓↓	↓↓
Urine output	→	↓	↓↓	↓↓
Respiratory				
End-tidal CO ₂	→	→ ↑	→ ↑	↑
pCO ₂	→	↑	↑	↑
Arterial pH	→	→ ↓	↓	↓

CO₂, Carbon dioxide; pCO₂, partial pressure of carbon dioxide.

5. Post-operative Patient Management

Limited laparoscopic procedures (i.e. laparoscopic varicocelectomy or diagnostic laparoscopy) may allow discharge of patients the same day. More extensive procedures may require between 1 to 3 days of hospital stay. The patient is usually given clear liquids upon returning to the outpatient area or the hospital floor. A regular diet is provided either the evening of surgery or the morning thereafter.

Ambulation depends on the type of procedure performed, as well as the overall health status and morbidity of the patient prior to surgery. The healthy patient after a minor or major laparoscopic procedure is encouraged to ambulate within 4 or 12 hours after the procedure.

The Foley catheter is either removed while the patient is still in the operating room (pneumoperitoneum \leq 2 hours), or later in the day or the next morning (pneumoperitoneum \geq 2 hours). Nasogastric tubes are removed in the operating room immediately upon completion of the procedure.

Antibiotics, with one dose having been administered before the procedure, are continued over 24 hours. Laboratory values (hemoglobin, hematocrit, sodium, bicarbonate, chloride, potassium, creatinine) are either obtained in a standardized manner postoperatively and the next morning or as needed. In

general, for a healthy patient undergoing an uneventful laparoscopic procedure, no laboratory studies are needed. However, after a major procedure or in high-risk patients, post-operative and 24 hour laboratory studies are warranted. This is especially important in the patient with pulmonary disease as the greatest risk of hypercarbia may occur 2-3 hours after the procedure. A postoperative chest radiograph is indicated only if there was extensive subcutaneous emphysema during the case or in the patient with significant pulmonary disease. Parenteral analgesia (e.g. morphine or toradol) is given as needed on the day of surgery and usually replaced by oral pain medication on the first postoperative day. If irrigant is left purposely in the abdomen at the end of the procedure, the male patient should be advised that as he ambulates he may notice some scrotal swelling. This is due to the irrigation fluid and will resolve over several days as it is absorbed.

6. Complications

In large series, the overall incidence of laparoscopic complications is in the range of 4%. Mortality is distinctly unusual, with a rate of 0.03%-0.08%.

1. Minimizing the incidence of complications during the laparoscopic learning curve.

Early in one's experience with laparoscopic surgery, it is wise to apply this minimally invasive approach to low risk surgical candidates of normal body habitus. In addition, it is advisable and recommended by many laparoscopic organizations as well as hospital credentialing boards, that the neophyte laparoscopic surgeon seek training in three arenas: a.) in-depth instructional courses including didactic, "live-case" transmissions, and "hands-on" laboratory sessions, b.) mentor training in which the surgeon in training views upwards of 5 procedures being done by an already skillful laparoscopic surgeon, and c.) a proctor/preceptor experience during which a trained laparoscopic surgeon oversees or assists, respectively, the initial procedures performed by the surgeon in training (SAGES, 1998). Further training can be obtained through self-teaching using videotapes and a pelvic trainer. The latter is extremely helpful in developing one's sense of laparoscopic proprioception and in becoming facile with laparoscopic suturing and knot tying. Recent data have clearly shown benefits in all areas of laparoscopy for those individuals who have taken the time to practice their laparoscopic skills using a pelvic trainer.

2. General procedural complications

Aside from training in manual skills, the neophyte laparoscopic surgeon must be educated with regard to prevention, recognition, and appropriate treatment of complications. Accordingly the following section covers the myriad complications that can occur with any laparoscopic procedure. Recognition, resolution, and prevention of these various problems are discussed.

A. Complications in relation to obtaining the pneumoperitoneum

1. Malfunction of equipment

A successful outcome of any laparoscopic procedure depends not only on the manual skills of the surgeon, but also on a proper working knowledge of all the high-tech equipment involved with performing these procedures. To ensure undisturbed functioning of all technology, the laparoscopist must be supported by a well-trained staff that must be capable not only to quickly recognize any equipment malfunction but also to provide immediate adequate response to correct the problem. In this regard, the Society of American Endoscopic Surgeons (SAGES) has issued a troubleshooting guide for video and electronic failure.

2. Complications associated with closed access (Veress needle placement)

Preperitoneal placement

Preperitoneal placement of the Veress needle may preclude successful trocar placement (Figure 2). If not recognized early, 3 to 4 liters of CO₂ may be inflated; indeed, once this much CO₂ has been insufflated into the preperitoneal space, many signs indicative of correct intraperitoneal insufflation may be present (i.e. distension, tympanic sound on percussion). The first trocar is usually placed and all signs of proper placement are evident.

The first sign of preperitoneal insufflation is that there may be high insufflation pressures at low volume. Also, unequal distention of the abdomen may occur. If these early signs are missed, then after trocar placement, the laparoscope reveals only fat; the intraperitoneal viscera are not seen.

The next step is to evacuate the CO₂ through the sidearm of the trocar and proceed with an open insertion technique. The initial incision can be widened, and the peritoneal surface grasped with a pair of Allis clamps and incised. A Hasson cannula is then secured in place, as previously described, and the peritoneal cavity is insufflated.

Several steps can be taken to avoid this complication. Firstly, upon initial insufflation, if the Veress needle is preperitoneal, pressures will usually be higher than the maximum initial allowable pressures of 10 mm. Secondly, if on initiating CO₂ insufflation the intra-abdominal pressure is greater than 10mmHg then preperitoneal positioning of the needle tip should be suspected.

Vascular injuries

During initial placement of the Veress needle minor or major intraabdominal blood vessels may be punctured by the 14 gauge needle. The first sign of intravascular entry is blood appearing in the hub of the needle. Aspiration results in additional blood filling the syringe. As long as the needle has not been manipulated, it can usually be withdrawn without any excessive bleeding occurring. An alternate site for Veress needle placement or an open cannula insertion should be undertaken at this point.

To prevent this problem, it is important, when using an umbilical approach, in the average size adult, to direct the Veress needle 30° caudad, towards the hollow of the pelvis. In the obese patient, a more perpendicular route is recommended. Passing the Veress needle via a 12 mm incision, bluntly spreading the subcutaneous fat, and grasping and stabilizing the anterior fascia with an Allis clamp, all help to prevent this problem. These maneuvers become especially important in children, who have less space between intraabdominal structures and their abdominal wall. Alternate, non-midline sites for insufflation largely will preclude any significant vascular complications. Finally, in a case of vascular injury it is important that upon entry into the peritoneal cavity, that the path of the initial Veress needle passage be traced to assess the site of vascular injury; likewise, any hemodynamic instability during the procedure, especially when combined with a decreased field of view (i.e. the expanding yet unseen retroperitoneal hematoma decreases the working space within the peritoneal cavity) should alert the surgeon to the possibility of retroperitoneal bleeding.

Visceral injuries

During Veress needle placement, intraabdominal organs may be punctured. The initial sign and diagnosis of this complication consist of aspiration of blood, urine, or bowel contents through the Veress needle or, in the case of a solid organ, high pressures upon initial insufflation.

If immediately recognized management consists of simply removing the Veress needle. The Veress needle may then be reintroduced at a different site, or an open cannula placement can be pursued via a separate incision site. Upon entry into the abdomen, any bleeding site on the liver can be electrocoagulated; if there is a splenic laceration, this can be treated with the Argon beam coagulator or the use of fibrin glue or a patch of gelfoam or bovine collagen. A bowel or bladder entry by the Veress needle needs no further treatment.

This problem can be readily prevented by placement of a nasogastric tube and a transurethral indwelling bladder catheter to decompress the stomach and bladder, respectively prior to Veress needle passage. Stabilization or slight elevation of the abdominal wall fascia with towel clips or Allis clamps at the time of Veress needle puncture may create more space for safe insertion of the Veress needle. Likewise, insufflation should never be initiated unless the signs for proper peritoneal entry have been observed (i.e. negative aspiration, easy irrigation of saline, negative aspiration of saline, and positive drop test).

3. Complications related to insufflation and pneumoperitoneum

Bowel insufflation

If entry into the bowel is not recognized at the time of irrigation and aspiration through the Veress needle, then the surgeon may well insufflate the small or large bowel. The first sign of this problem is asymmetric abdominal distention. Associated signs may be passage of flatus and insufflation of only a small amount of CO₂ (< 2 liters) before high pressures are reached.

If this complication is suspected, then the insufflation line should be disconnected, the outflow of malodorous gas will immediately confirm bowel

entry. The needle can be withdrawn and Hassan cannula placement should be done at an alternate abdominal site.

Prevention of this problem is essentially assured if one properly goes through the aspiration/irrigation/aspiration tests recommended for safe Veress needle placement. Similarly, initial open insertion greatly decreases the chances of this complication.

Gas embolism

The CO₂ insufflant has a favorable solubility in blood as opposed to insufflants of air, helium, or nitrous oxide; however, CO₂ still may result in an air embolus. The most common cause of CO₂ embolism is puncture of a blood vessel or organ with the Veress needle followed by insufflation; this usually only occurs when the surgeon has ignored the aforescribed tests for proper entry into the peritoneal cavity. The first sign of intravascular insufflation is acute cardiovascular collapse. Other signs include, dysrhythmias, tachycardia, cyanosis and pulmonary edema. The diagnosis is usually made by the anesthesiologist due to an abrupt increase of end-tidal CO₂ accompanied by a sudden decline in oxygen saturation and then a marked decrease in end-tidal CO₂. Sometimes, a "mill-wheel" precordial murmur can be auscultated. In addition, the anesthesiologist may notice foaming of any blood sample due to the presence of insufflated CO₂.

The treatment is immediate cessation of insufflation and prompt desufflation of the peritoneal cavity. The patient is turned into a head-down, left lateral decubitus position (i.e. right side up), in order to minimize right ventricular outflow problems. The patient is hyperventilated with 100% oxygen. Advancement of a central venous line into the right heart with subsequent attempts to aspirate gas may rarely be helpful. The use of hyperbaric oxygen and cardiopulmonary bypass have also been reported.

This devastating complication can be precluded by meticulous attention to Veress needle placement and each of the recommended tests for intraperitoneal entry. Insufflation should never be initiated if the surgeon has even the slightest doubt about correct position of the Veress needle; in this situation, the surgeon should withdraw the Veress needle and immediately proceed with open cannula access.

Barotrauma

Prolonged elevated pressures (i.e. > 15 mm Hg) in children may result in barotrauma (Abdel-Meguid and Gomella, 1996). Prolonged high pressures may be caused by insufficient and infrequent monitoring of CO₂ pressures, malfunction of the insufflator, or additional pressures produced by auxiliary devices (i.e. argon beam coagulator or CO₂-cooled lasers). Furthermore, barotrauma may be caused by ventilation techniques using positive end-expiratory pressure resulting in rupture of a pulmonary bleb or bulla.

The initial sign of barotrauma may be hypotension due to decreased cardiac output secondary to an acute drop in venous return caused by compression of the vena cava. Also, a pneumothorax or pneumomediastinum

may develop due to high ventilation pressures. Increased intraabdominal pressures may also induce a hiatal hernia.

The anesthesiologist will usually alert the surgeon to the problem of excessive intra-abdominal pressure; this usually presents as an increase in ventilation pressures. The surgeon should proceed to desufflate the abdomen and, once the hemodynamic changes have been reversed, reinitiate the pneumoperitoneum at 10 mm Hg. A malfunctioning insufflator should be replaced. Also, if one is using an argon beam coagulator or CO₂ cooled laser device, the sidearm on one port should be left open in order to allow the high pressure, excess gas to readily escape.

These problems are avoided by the alert, meticulous surgeon. The insufflator should always be checked prior to initiating the procedure: at maximum inflow settings, gas should flow at 1-2 liters/min through the Veress needle at < 2mm Hg pressure down the opened, unconnected insufflation line and when the line is purposely kinked by the surgeon, the insufflator recorded pressure should rapidly rise to its preset limit (i.e. usually 15 mm Hg), the inflow of CO₂ should cease, and the high pressure alarm should sound. Again, troubleshooting the insufflator should be part of the routine prelaparoscopy check in every case.

Subcutaneous emphysema

This problem develops due to improper placement of the Veress needle or, more commonly, due to leakage of CO₂ around ports. The latter situation occurs when port site incisions are too large, the procedure is particularly lengthy or when high intraabdominal pressures are used. The pathognomonic sign is readily palpable crepitus over the abdomen and thorax; in male patients a pneumoscrotum may also develop.

If the problem is due to the improper placement of the Veress needle, then withdrawal of the Veress needle and an open insertion are recommended. If the problem develops intraoperatively then the surgeon should check for any gas leakage around a port site. If this is found, the surgeon can either place a purse-string suture around the port or change the trocar to a larger size. Also, the surgeon should consider reducing the insufflation pressure.

This complication is eminently avoidable if the surgeon adheres to all of the diagnostic tests for proper Veress needle placement and if the port site incisions are carefully tapered to the size of the port to be placed. In this regard it is also important to place each port such that it is pointing towards the surgical field in order to avoid continued forceful redirection of the port during the procedure which results in widening of the tissue tract around the port and subsequent escape of CO₂ into the surrounding subcutaneous tissues. In addition, the cannulas need to be secured so they do not pull back into the abdominal wall tissues; to this end the surgeon can use either a self retaining type of cannula or may elect to simply use a suture to fix the sidearm of a smooth walled port to the skin thereby precluding its retraction beyond a certain point. The surgeon must be careful to never use one of the older plastic retaining collars with a metal trocar; this situation greatly increases the chances of

inadvertent electrosurgical injury due to stray current along the exposed shaft of the “now” insulated metal trocar. Fortunately, these disposable plastic collars have largely been removed from most operating rooms. Also, the insufflator must be tested prior to each case to make sure it is functioning properly, such that when high pneumoperitoneum pressures develop, the inflow of CO₂ automatically ceases.

Pneumomediastinum and pneumopericardium

Gas leaking along major blood vessels through congenital defects or secondary enlargement of openings in the diaphragm may lead to pneumomediastinum and/or pneumopericardium. While a pneumomediastinum is usually not associated with specific clinical symptoms, a pneumopericardium may result in impaired cardiac function. The diagnosis is rarely made during the procedure unless cardiac impairment occurs. Usually the diagnosis is made on a chest radiograph taken in the recovery room. However, if during a procedure, there is sudden cardiac decompensation, the same maneuvers are undertaken as described for treatment of a suspected gas embolism: interruption of the procedure and desufflation of the abdomen. If there is a strong suspicion of pericardial tamponade, pericardiocentesis is indicated.

Prevention of this problem is similar to the means to avoid subcutaneous emphysema: keep the intra-abdominal pressure at <= 15mm Hg, make sure all ports site incisions are tight around the laparoscopic cannulas, and make sure all cannulas are well seated in the peritoneal cavity.

Pneumothorax

A pneumothorax may be associated with pneumomediastinum, barotrauma and subsequent rupture of alveoli, or direct puncture of the pleural space with a trocar (Pascual et al, 1990). The earliest signs of this problem may be the development of subcutaneous emphysema, especially in the neck and chest area. More ominous signs such as hypotension and decrease breath sounds with an increase in ventilatory pressure are indicative of a tension pneumothorax. While a chest radiograph will confirm the diagnosis, the development of pulmonary collapse with loss of breath sounds on one side, mandates immediate decompression of the chest by passage of a 16-gauge needle via the second or third intercostal space in the midclavicular line or tube thoracostomy if a tension pneumothorax is diagnosed. Prevention of this complication again harkens back to trying to keep the pneumoperitoneum pressure as low as possible (10-15mm Hg) and in making sure that all trocars are placed below the 12th rib.

4. Complications during open access (Hasson technique)

Potential problems associated with the initial passage of the Hasson trocar are similar albeit less frequent than problems associated with a closed Veress needle pneumoperitoneum. The biggest major risk in this regard is injury to underlying viscera while traversing the peritoneum. In a densely scarred

abdomen, the bowel may be adherent to the underside of the abdominal wall and hence may still be injured. If a bowel injury is recognized early, it can often be repaired via the same incision that was made for insertion of the open access cannula. While vascular injury with this approach is distinctly rare; the surgeon needs to realize that even with an open access this devastating complication can occur (Hanney et al, 1999).

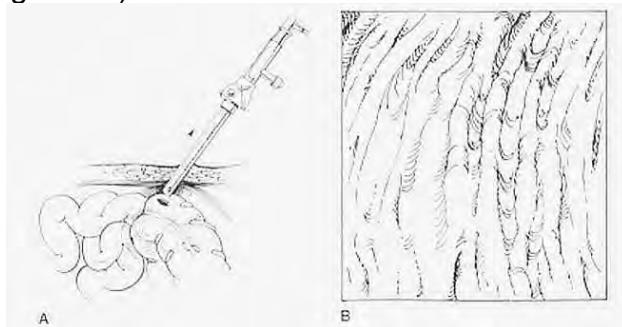
The only minor risk in using the open access technique, is failure of the surgeon to obtain secure transfascial retaining sutures on either side of the cannula. If this is not done, the bulb of the Hasson cannula will not be seated tightly into the incision thereby resulting in significant leakage of gas, resulting in significant subcutaneous emphysema. One way to prevent this problem is to also place a pursestring suture in the fascia to better secure it to the bulb of the Hasson cannula. In addition, there are some Hasson cannulas that have a retention balloon that can be inflated in the peritoneal cavity and then drawn up tightly against the underside of the abdominal wall; an outer foam sealing ring can then be advanced down the extra-abdominal shaft of the cannula thereby sandwiching the abdominal wall between the inflated balloon and the foam seal; this effectively precludes any leakage of gas during the case (e.g. Bluntport, US Surgical Corp., Norwalk, CT). This is especially effective when doing retroperitoneoscopic procedures.

5. Complications related to initial “blind” placement of the first trocar after obtaining a Veress needle pneumoperitoneum

Injury to gastrointestinal organs

Perforation of small or large intestine with passage of the primary port is the most common cause of trocar-induced injury of gastrointestinal organs. Other organs (i.e. stomach) are affected much less frequently. Given the lateral positioning of the spleen and liver, injury of these organs with the passage of the primary trocar is distinctly unusual (Figure 14).

Figure 14 A, The trocar has punctured one wall of the bowel. B, View of bowel mucosa as seen through the laparoscope. (From Clayman RV, McDougall EM (eds): Laparoscopic Urology. St. Louis, Quality Medical Publishing, 1993)



The first sign that one has entered the bowel is dependent upon whether the injury has been through one wall or both walls (i.e. a “through-and-through” injury) of the bowel. In the former instance, as soon as the laparoscope is introduced, the surgeon sees the mucosal folds of the interior of the bowel. However, with a “through-and-through” injury, the diagnosis is not made until the first secondary trocar is passed; at that time, the surgeon should routinely pass the laparoscope through the secondary port in order to inspect the puncture site

of the initial port. The trocar will be seen to be passing completely through both walls of the bowel. If the surgeon fails to routinely check the insertion site of the primary trocar, this injury will not be noted, if at all, until the end of the case when the trocars are being removed. A missed bowel injury of this nature, leads to peritonitis and possible death.

In the case of a one wall injury of the bowel, the surgeon can elect to leave the trocar in place and pass a second trocar in another location using an open access technique. Upon inspecting the abdomen, the site of injury to the bowel will be immediately apparent as the initial trocar will still be residing in the bowel. At this time, the surgeon, may either elect to open and repair the bowel or if laparoscopically skilled may place two more ports and proceed to close the bowel using laparoscopic suturing or stapling techniques. Consultation with general surgery is prudent at the initial injury in the event that post-operative complications occur and require further evaluation or management.

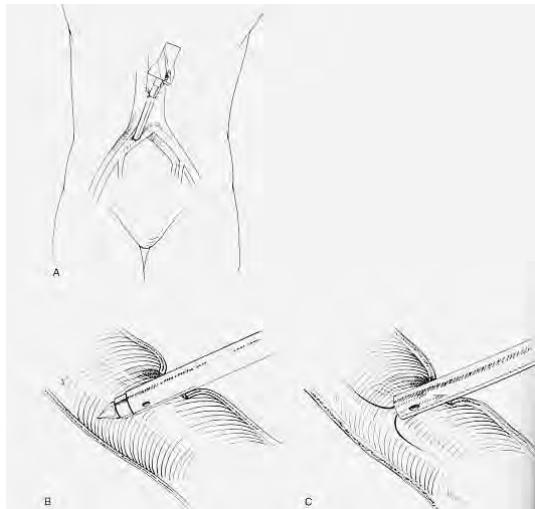
When the injury of the bowel is “through-and-through”, the safest path is to open and proceed with repair or if necessary resection of the injured bowel segment and reanastomosis. Rarely, one may consider, laparoscopic repair by placement of sutures, or, if necessary, resection of bowel and reanastomosis with laparoscopic GIA staplers. In either case, the abdomen needs to be irrigated with 4-5 liters of saline containing an antibiotic solution and the patient needs to be placed on broad spectrum, triple drug, antibiotic coverage.

This complication is best prevented by use of an open access technique. Furthermore, mechanical and antibiotic bowel preparation in patients with a history of extensive prior abdominal surgery is highly recommended. To decrease the risk of stomach perforation, patients should refrain from any oral intake for 12 hours before surgery. To decompress the stomach, a nasogastric or orogastric tube should be placed before puncture of the abdomen with the Veress needle.

Injury to intraabdominal vessels

Major vascular injury is a rare but serious complication occurring in 0.11-2% of cases (Hanney et al, 1995) (Figure 15). Aorta and common iliac vessels are most frequently involved. The inferior vena cava is less affected due to its lateral location in relation to the aorta; likewise the common iliac vein is rarely involved given its posterior position in relation to the common iliac artery. Rarely, in a patient with adhesions or prior surgery, intestinal mesenteric vessels supplying a “fixed” loop of bowel, may be injured.

Figure 15 A and B, The right common iliac artery has been punctured by a trocar. C, As soon as the obturator is removed, blood fills the sheath. (From Clayman RV, McDougall EM (eds): Laparoscopic Urology. St. Louis, Quality Medical Publishing, 1993)



The first sign of a major vascular complication is the onset of sudden hypotension and associated tachycardia. If the trocar has not been moved, then as the obturator is withdrawn, the diagnosis is made immediately, as there is a pulsatile (i.e. arterial) or nonpulsatile (i.e. venous) profuse return of blood from the trocar sheath. If the trocar has been displaced from the injured vessel, then, depending upon the vessel injured, the surgeon will see either blood rapidly accumulating in the abdominal cavity, a mesenteric hematoma, or, in rare cases, the blood may preferentially accumulate retroperitoneally in which case, due to the expanding retroperitoneal hematoma, the space within the peritoneal cavity appears to be markedly reduced and actively decreasing.

The response to this complication must be rapid. A vascular or trauma surgeon should be called to the room. If blood is coming through the trocar, then the trocar should be left in place. An emergency laparotomy is done and the trocar is followed to its point of entry into the vessel. Controlling sutures can be placed on either side of the trocar; as such, as the trocar is withdrawn, the wound can be rapidly closed with minimal blood loss.

If the injury is discovered at the time of passage of the laparoscope (i.e. the trocar is no longer residing in the vessel), then the sheath and laparoscope can be swung up to the underside of the abdominal wall and an immediate cut down can be done on top of the laparoscope and sheath, thereby providing for a rapid and safe laparotomy. The site of injury must be rapidly located and controlled. Again, the aid of a vascular or trauma surgeon in this case is quite helpful.

The best management of vascular trauma is to never experience it. In this regard, knowledge of the exact location and possible anatomical variations of major intraabdominal blood vessels is mandatory. The CT scan should be reviewed prior to passage of any trocars to look for any caval or other abnormalities of the great vessels. Due to limited intraperitoneal space, special care must be given to trocar placement in children. Strict adherence to laparoscopic guidelines, such as being certain that all of the safety signs of passage of a Veress needle are present before proceeding with trocar passage, obtaining an adequate pneumoperitoneum prior to trocar passage (e.g. intraabdominal pressure may be raised to 25 mm Hg temporarily for placement of

the primary trocar), and avoidance of initial trocar passage through an abdominal scar are all important measures in preventing this problem. Also, use of the non-bladed trocars is helpful in avoiding this problem; indeed, in many operating rooms, bladed trocars are no longer used.

With respect to the pneumoperitoneum: “It’s either perfect or it’s not; if it’s not perfect, then it is imperfect” (Clayman), and an alternative site for Veress needle passage or open access should be sought. If there is any doubt with regard to the creation of a proper pneumoperitoneum, then an open access technique should be the next step. It is not the Veress needle that does the damage, rather it is the blind passage of the first trocar into a less than perfect pneumoperitoneum.

Injury to the urinary tract

Trocar injuries of the urinary tract, to date, have reportedly only affected the bladder. The initial sign of this problem is pneumaturia or macroscopic hematuria. The diagnosis is confirmed by retrograde intravesical instillation of indigo-carmine diluted with saline; this will allow the surgeon to rapidly identify the cystotomy site.

The injury can be repaired laparoscopically either with laparoscopic suturing techniques or by use of the laparoscopic tissue stapler (Ostrzenski and Ostrzenska, 1998). Extensive defects may require open surgical repair. These injuries should always be closed, and never left to heal on “their own” with prolonged Foley catheter drainage.

Prevention of this problem is essentially eliminated by preoperative placement of a urethral catheter to drain the bladder for all major laparoscopic urologic cases. Not only will this largely preclude bladder injury, but it provides the necessary means for monitoring urine output during laparoscopic urologic procedures, which are almost invariably in excess of two hours in duration.

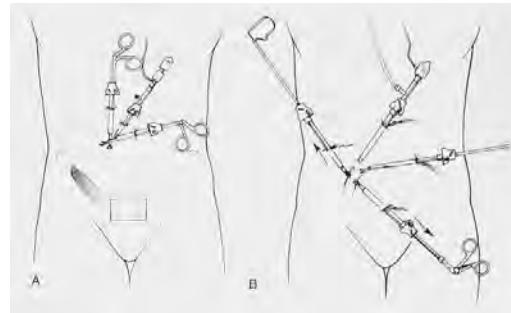
B. Complications related to placement of secondary trocars

1. Position related problems

There are three potential problems that occur when the secondary trocars are not properly positioned: “crossing swords”, “striking handles”, and “rollover”. The problem of “crossing swords” is due to the trocars being placed too close to one another; as a result the intra-abdominal portions of two trocars cross each other such that the two can not easily be used to deliver instruments to the same surgical site (Figure 16). Similarly the problem of “striking handles” is also due to trocars being placed too close to one another; as a result the surface portions of the trocars strike one another on the abdominal surface again precluding delivery of instruments to a specific surgical site. “Rollover” is a variant of the “crossing swords” problem only it occurs between the laparoscope and an instrument. Instead of running parallel to the surgical site, the primary cannula holding the laparoscope and one of the instrument-holding secondary ports cross over one another; as the instrument is advanced toward the surgical site, it strikes and is

deflected by the larger laparoscope, thereby “rolling over” the laparoscope and hence moving out of the field of view.

Figure 16 A, The trocars have been placed too close to each other; hence, the intra-abdominal portions of the trocar sheaths are also too close to each other, thereby impairing use of instruments passed through the ports. B, Correct spacing of the trocars eliminates this problem. (From Clayman RV, McDougall EM (eds): Laparoscopic Urology. St. Louis, Quality Medical Publishing, 1993)



Usually these problems are of a minor annoyance, and the surgeon and assistant need only to experience the problem once in order to adjust for it. Specifically, in order to avoid the problem of “striking handles” the sheaths can be withdrawn a bit from the abdomen thereby increasing the space between the handles of the trocars. The problem of “crossing swords” and “rollover” can be remedied by moving the handles of the crossing trocars closer to one another thereby moving the tips of the trocars further apart. When this is done to correct a “rollover” situation, the surgical site may be displaced into one corner of the monitor; however, the desired delivery of the instrument to the surgical site can then be accomplished.

The best way to handle these situations is to not create them. Accordingly, proper placement and direction of each trocar is essential. For some procedures, such as pyeloplasty, this may be accomplished by placing all of the trocars on the same line (i.e. midline) so they are all working parallel to each other while for other procedures, such as nephrectomy, the goal is to place the trocars such that they surround the surgical site forming a diamond pattern within which lies the kidney. Lastly, the surgeon should avoid advancing sheaths too far into the abdomen. This can be accomplished by selecting the proper length of trocar for each patient and using trocars that have a self retaining design. Lastly, if trocar interactions become particularly vexing during a procedure, then the surgeon should not hesitate to place an additional 5 mm secondary trocar to eliminate the problem.

2. Injury to abdominal wall vessels

The inferior epigastric vessels seem most prone to injury during the placement of secondary trocars. These vessels do not transilluminate. The first sign that a trocar has injured an abdominal wall vessel is blood dripping from the tip of the trocar and/or droplets of blood visible on the bowel underlying a port site. The diagnosis of the bleeding site can be made by cantilevering the trocar into each of the four quadrants, until cessation of blood flow is seen.

At times the problem can be resolved by passage of an articulating electrosurgical scissors via one of the other secondary ports. Using a 30 degree laparoscope the site of bleeding can be visualized and electrocoagulated.

However, if these specialized instruments are not available, then placement of a #1 absorbable suture across the entire quadrant of the identified bleeding site is recommended. This can be done using a #1 Prolene suture on a large (XLH) needle or a Keith straight needle. After traversing the abdominal wall, the needle is guided across the bleeding site and towards the skin surface by the use of laparoscopic grasping forceps. Alternatively, the port can be removed and a Carter Thomason cone can be placed in the wound; the Carter Thomason needle grasper can then be used to place the #1 suture, following which the port is replaced. On the surface of the abdomen the suture is tied over a gauze bolster; the port is left in place and can still be used throughout the procedure.

This problem can usually be prevented if one uses a 30-degree laparoscope to carefully examine the underside of the abdominal wall prior to port placement. In most nonobese individuals, this inspection will reveal the inferior epigastric vessels and they can accordingly be avoided. Also, transillumination of the abdominal wall during trocar site selection can help avoid injury of more superficial abdominal wall vessels. In addition, the use of a Kelly clamp to spread the subcutaneous tissue prior to trocar placement and the use of double bladed or cone tipped obturators, rather than pyramidal bladed, obturators, may further decrease inadvertent vascular injuries. Furthermore, in most individuals, if all non-midline secondary ports are placed at least 5 cm off of the midline, the inferior epigastric vessels can be avoided. Finally, use of the nonbladed trocars should further help in preventing this problem as the epigastric vessels are pushed aside as the point of entry into the peritoneal cavity is dilated; indeed, in many operating rooms, bladed trocars are no longer used.

C. Complications related to the surgical procedure

1. Bowel injury: Electrosurgical etiology

Electrosurgically induced thermal injury may occur due to one of four mechanisms: inappropriate direct activation, coupling to another instrument, capacitive coupling, and insulation failure. Active electrode trauma by unintended activation causes direct bowel or other organ injury; this problem is the result of accidental activation of an electrosurgical instrument. This may occur when the instrument is left unobserved within the peritoneal cavity or when electrode activation is carried out by someone other than the primary surgeon. Furthermore, active electrode trauma may be seen when coagulation extends beyond the intended site and reaches other adjacent structures (i.e. bowel, blood vessels, nerves, ureter); this is more commonly seen when using high electrocoagulation settings as opposed to blend or pure cutting current. Direct coupling may occur when the active electrosurgical instrument touches another instrument which is in direct contact with other tissue (i.e. bowel). If this happens outside of the field of view provided by the laparoscope it may remain unnoticed by the surgical team. Injury due to capacitive coupling occurs when the surrounding charge which is intrinsic to all activated monopolar electrodes, is not allowed to conduct back to and disperse via the abdominal wall.

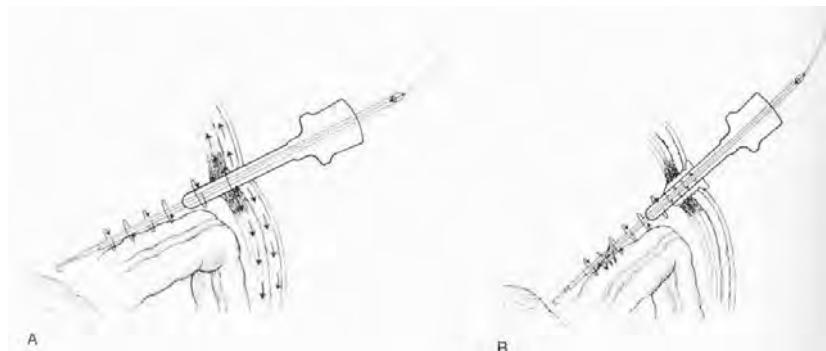


Figure 17 Capacitive coupling. A, Charge surrounding the activated monopolar electrode is conducted back to the all-metal trocar and dispersed by the abdominal wall. B, The electrosurgical instrument is being used through a metal trocar that has been anchored to the skin with a nonconductive plastic grip; accordingly, the electrical field cannot be conducted to the abdominal wall because the plastic retainer acts as an insulator; a stronger electrical charge is thus conducted to any other tissue in contact with the cannula. (From Walsh PC, Retik AB, et al (eds): Campbell's Urology. Philadelphia, Saunders, 2002)

This condition may develop when a metal cannula is anchored to the skin with a nonconductive plastic grip (Figure 17). As a result, the electrical field, which builds up around the activated electrosurgical instrument, cannot be conducted to the abdominal wall as the plastic retainer acts as an insulator. This may lead to a high power density along the portion of the metal cannula that is inside the abdomen; the electrical charge built up on the cannula can then travel to other tissues in contact with the cannula. Similarly, capacitive coupling may constitute a risk when electrosurgical probes are used through operating laparoscopes which are in turn inserted through plastic sheaths. The metal shaft of the laparoscope then becomes a repository for electrical current and may discharge this energy to any tissue in contact with the laparoscope. The risk of this complication to occur is also increased when older generators with high voltage output, and/or electrodes with thicker diameters are used, especially in the coagulation rather than the cutting mode (Munro, 1997). Lastly, insulation breakdown may allow current to escape along the shaft of the instrument thereby harming tissues that are otherwise outside the field of view of the laparoscope. Insulation breakdown may be a result of repeated use, resterilization, or mechanical damage to the instrument during repeated insertion through a trocar during the case. Intraoperatively, thermal injuries of the bowel may present as whitish spots on the serosal lining. In severe cases the muscularis mucosa or the intestinal lumen may be seen. However, in many patients the event of thermal injury of the bowel is not realized at the time of the procedure. Postoperatively, the patient with unrecognized bowel trauma, may not develop fever, nausea or signs of peritonitis for 3 to 7 days; the full extent of the bowel necrosis may take up to 18 days to fully develop (Abdel-Meguid and Gomella, 1996). As such, the problem often does not become manifest until the patient has been actually discharged from the hospital.

Accordingly, any patient who develops a fever beyond postoperative day 1 or who complains of increasing abdominal discomfort, must be ruled out for a bowel injury. Abdominal radiographs are notoriously inaccurate as the CO₂ from

the laparoscopy may remain as "free air" for upwards of two weeks after the procedure; however, an ileus pattern is usually present. The more sensitive test is an abdominal CT scan with oral contrast and with delayed films. Laboratory values may be remarkable for leukocytosis. However many of these patients have a normal or even low white blood cell count; the key in this regard is the invariable presence of a "left shift" (neutrophilia).

Minor thermal injuries of the bowel may be managed conservatively aided by administration of antibiotics and an elemental diet. Indeed, a closed fistula may develop which will heal with this approach. However, if the patient does not respond rapidly or develops worsening peritonitis, open surgical exploration is mandatory. Thermal injury caused by monopolar cautery often causes tissue damage that extends beyond the visible area of necrosis. With this in mind, the surgeon should perform a bowel resection with a safety margin of 6 cm on either side prior to completing an end-to-end anastomosis (Abdel-Meguid and Gomella, 1996). Thermal injury caused by bipolar electrosurgery is more confined to the visible area of damage; as such, if the injury is small, it can be managed by simple excision of the defect and closure of the bowel wall. More extensive injuries, involving over half of the circumference of the bowel, should be treated by excision of the affected segment of the bowel followed by an end-to-end anastomosis (Abdel-Meguid and Gomella, 1996).

The goal of every laparoscopic surgeon is to never experience a thermal complication. To this end there are several actions the surgeon can take to lessen the risks. Firstly, electrosurgical instruments must be carefully inspected before use for any "breaks" in the insulation; if such are found, the instrument needs to be sent out to be recoated. Next, electrosurgical instruments should never be left unintended within the abdomen; when not in use, they must be removed from the abdomen. Also, control of electrode activation should be performed ONLY by the primary surgeon. The foot pedal should be placed such that only the surgeon can depress it. Also, isolating the area to be cauterized from surrounding tissues (i.e. vessels, nerves, ureter), as well as the use of bipolar electrocautery reduces the risk of thermal injury to other tissues. In addition, the electrosurgical device should never be activated unless the entire extent of the metal portion of the instrument is in view. In this manner, both inadvertent direct injury to adjacent tissue as well as direct coupling to another instrument can be avoided. Problems of capacitive coupling can be precluded by not creating a situation in which a mixture of conducting and nonconducting elements are used by the surgeon (e.g. metal trocars combined with plastic retainers or using electrosurgical devices through operating laparoscopes passed through plastic trocars). In addition, use of modern generators and small diameter electrodes will also significantly decrease the risk of capacitive coupling (Munro, 1997); as will greater use of blend or pure cutting current. The high voltages needed for pure coagulation current pose the greatest threat for electrosurgical injury, especially through the mechanism of capacitive coupling. In this regard, whenever coagulation current is to be used, it is better to already have the electrode in direct contact with the tissue to be coagulated prior to activation of the probe. In contrast, for incising tissue electrosurgically, with the

electrode in the cut mode, the probe is activated a millimeter or less off of the tissue and then brought to the tissue thereby cutting by a vaporization mechanism. Lastly, to further decrease the chance of electrosurgical injury, there are now instruments which are capable of active electrode monitoring and thus can “sense” any break in the insulation; when this occurs, the instrument automatically shuts off (Encision, Boulder, CO).

2. Bowel injury: Mechanical

Inadvertent mechanical damage can be caused by a wide variety of sharp and blunt instruments (i.e. laparoscopic graspers, scissors, retractors). This type of injury is more visible to the surgeon and is usually discovered intraoperatively. Postoperatively, symptoms develop much earlier than with an electrosurgical injury. Direct visual identification during the procedure, allows the surgeon to repair the injury laparoscopically, even though the patient has not had a formal bowel preparation. Given its localized nature, bowel resection is rarely necessary. The abdomen should be irrigated copiously at the end of the procedure with 3-4 liters of an antibiotic containing solution.

If a bowel injury is missed during the procedure, then symptoms of fever, nausea, ileus, and peritonitis will develop in the very early postoperative period. Diagnosis is confirmed by an abdominal CT scan with oral contrast. This type of injury should be managed expeditiously with a return to the operating room to correct the problem; local excision or resection of bowel with subsequent end-to-end anastomosis depending on the degree of damage and/or concomitant inflammatory changes may be required.

Delicate handling of tissue with laparoscopic instruments by the main surgeon and the assistant(s) is essential to avoiding this complication. Likewise it is important that introduction of laparoscopic instruments into the peritoneal cavity be done under strict visual control. Instruments should never be left unattended; if they are not in use, they should be withdrawn from the abdominal cavity. Prudence and deftness of touch are essential characteristics of both the successful open and laparoscopic surgeon.

3. Vascular injury

Fortunately, direct vascular injury during laparoscopic dissection is a rare event. The small nature of the instrumentation, the limitations on surgical speed, and the magnification of the surgical field by the laparoscope all combine to decrease this potential problem.

During renal dissection in particular, the chances of a vena caval or renal vein injury are very real. When this occurs, the surgeon can undertake several steps to resolve the bleeding. First, the pneumoperitoneum pressure can be raised to 25 mm Hg, thereby slowing or stopping any venous bleeding. Using the irrigator/aspirator, the blood can be cleared and the bleeding site identified. Next, via one of the 12 mm ports, a gauze sponge can be introduced into the abdomen and handled with a grasping forceps, thereby allowing the surgeon to identify and tamponade the area of bleeding. If the injury is small (i.e. 1-2 mm), it may respond to simple tamponade; alternatively, a hemostatic patch and/or fibrin

glue may be applied. If the injury is larger, then the surgeon must decide whether to obtain a vascular consult and proceed to convert to an open procedure or to attempt securing the injury with a laparoscopic Satinsky and proceeding with intracorporeal suturing, either free-hand or with an EndoStitch (U. S. Surgical, Inc., Norwalk, CT). Throughout this period, it is essential for the anesthesiologist to administer sufficient fluids or blood replacement to preclude a hypovolemic state, as if this occurs the patient has a higher risk of possible air embolism (O'Sullivan et al, 1997).

An aortic, common iliac or renal artery injury is much more difficult to resolve laparoscopically. While the latter, if it occurs during a planned nephrectomy, can be handled by expeditiously taking the renal artery with a clip or vascular stapler, the former almost invariably leads to an open repair. In this case, the area of injury should be tamponaded with a laparoscopic forceps. A vascular surgeon can be called into the room and the surgeon can proceed to rapidly make a midline incision by swinging one of the midline ports up to the underside of the abdominal wall and cutting down on the shaft of the port. The tamponading laparoscopic forceps directs the surgeon immediately to the site of injury, which can then be properly repaired.

4. Injury to the urinary tract

Bladder injury

Urinary tract injuries during laparoscopy have been reported most extensively in the gynecological literature and lie in the 0.02-8.3% range (Ostrzenski and Ostrzenska, 1998). Usually these occur to the bladder at the time of initial trocar placement. Electrocautery dissection, blunt and sharp dissection (laparoscopic scissors), and laser dissection have been identified as leading causes for bladder injury (Ostrzenski and Ostrzenska, 1998). Concomitant bladder or pelvic anomalies or pathologic conditions (acute or chronic inflammation, prior pelvic or bladder surgery, endometriosis, malignant infiltration, bladder diverticula, amyloidosis, or previous radiation) are predisposing factors which increase the chances of this complication (Ostrzenski and Ostrzenska, 1998).

Bladder injury may remain undetected at the time of surgery and some patients may present with clinical problems after being discharged from the hospital. In some of these patients a urinary fistula may develop postoperatively.

When a bladder injury has occurred, the intraoperative signs may be subtle. One of the first signs is the presence of blood or gas in the Foley catheter bag. Also the surgeon may notice the presence of clear fluid welling up in the pelvis, although if irrigation has been used during the procedure, this sign is often obscured.

Postoperatively, if the bladder injury was missed, the patient may develop oliguria and urinary ascites; this may be accompanied by hyponatremia and rarely hyperkalemia with a mild elevation of the serum creatinine. In patients who have been discharged from the hospital due to the minor nature of their laparoscopic procedure, they may contact their physician complaining of lower

abdominal discomfort, abdominal swelling, fever, and, in the case of a gynecological procedure, a pink or clear vaginal discharge.

The intraoperative suspicion of a bladder injury can be confirmed by the injection of saline mixed with indigo carmine, through the Foley catheter. Postoperatively, the diagnosis can be made by radiologic examinations (pelvic ultrasound, pelvic CT scan, and/or voiding cystogram). Similarly, an endoscopic examination with the injection of 5 ml indigo carmine intravenously is helpful if a fistula is suspected; the surgeon can then look for bluish tinted vaginal or rectal discharge.

The intraoperative diagnosis of a bladder injury can be followed by laparoscopic repair: suturing with absorbable suture, closure of the defect with a laparoscopic stapler, or use of preformed suture loops to encircle and secure the cystotomy. More extensive defects may require open incisional repair.

When diagnosed postoperatively, the surgeon must first determine whether the drainage is extraperitoneal or intraperitoneal. Extraperitoneal injury without any complicating additional problems may be treated by simple placement of a transurethral indwelling Foley catheter. Intraperitoneal drainage is an indication for subsequent laparoscopic or open repair.

Prevention of bladder injury requires preoperative placement of a Foley catheter. Strict adherence to basic laparoscopic principles remains the hallmark of uncomplicated laparoscopic procedure; in this regard, avoidance of excessive coagulation near the bladder and dissection with exact knowledge of bladder anatomy (i.e. urachus, medial umbilical and vesicocervical ligaments) are key.

Ureteral injury

Ureteral injury is usually a result of thermal damage caused by dissection using monopolar electrocautery in the immediate vicinity of the ureter. Its incidence in laparoscopic hysterectomy is 1%, it may also occur during laparoscopic endometriosis ablation, tubal ligation, and has been reported during pelvic lymphadenectomy (Lin and Grow, 1999). Typically, ureteral injuries remain unnoticed throughout the laparoscopic procedure. Within 2 to 3 days after surgery, patients may present with abdominal and/or flank pain, fever, signs of peritonitis, and leukocytosis.

The intraoperative diagnosis is made by the astute laparoscopist when urine is suspected of welling up in the wound. However, if irrigation has been used during the procedure, this sign will invariably be obscured. If the operating surgeon has a high level of suspicion then intravenous indigo carmine can be given and a careful inspection can be made for "blue" tinged fluid. As opposed to a bladder injury, macroscopic hematuria or pneumaturia is distinctly unusual with this injury.

As such, most of these diagnoses are made during the postoperative period when an intravenous pyelogram (IVP) and/or abdominal/pelvic CT scan is ordered due to the patient complaining of abdominal swelling and the physical signs of urinary ascites. Dependent upon the function of the contralateral kidney and the amount of urine leakage, serum chemistries may reveal hyponatremia and rarely hyperkalemia with a mild elevation in the serum creatinine.

If identified intraoperatively, the injury can be repaired laparoscopically. If the injury is due to mechanical trauma, simple closure of the defect can be accomplished with laparoscopic suturing techniques followed by stent placement. If the injury is due to monopolar electrosurgical current, then a formal resection of the affected area and an end to end spatulated ureteroureterostomy is indicated or ureteral reimplantation if the level of injury is at the ureterovesical junction. This can be done laparoscopically but usually requires most laparoscopists to convert to an open procedure. A indwelling ureteral stent is always placed.

If the problem is detected in the postoperative period, then the first step is to place an indwelling stent and a bladder drainage catheter. Once a cystogram reveals reflux through the stent without extravasation, the bladder drainage catheter can be removed. The stent is left in place for 6-8 weeks. Careful follow-up is then necessary to rule out the development of a ureteral stricture that may require endourological or open surgical repair.

Prevention of this injury again harkens back to the importance of the surgeon's knowledge of laparoscopic anatomy and the course of the ureter with regard to its topographical relation to other anatomical structures (i.e. medial umbilical ligament, round ligament or vas deferens, and the common iliac artery). During dissection, the use of monopolar electrosurgical coagulation current should be used with great discretion around the ureter. In particular the wattage should not exceed 20-30 watts, fine tipped electrosurgical instruments should be employed, and the duration of discharge should be brief (i.e. short burst of current rather than 2-5 second discharge).

5. Injury to nerves

There is no more vexing problem to physician and patient alike than a postoperative nerve injury; a technically and surgically successful procedure is marred by an acute complication in a totally unrelated area, which may have chronic consequences. This problem is invariably due to patient positioning and the duration of the procedure. If the patient is inadequately positioned and/or padded, nerve damage may result due to abnormal stretching or compression. Among position-related nerve injuries, the brachial plexus is most often affected. Injury may be inflicted in several ways: a. abduction of the arm beyond 90 degrees, b. extreme outward rotation of the head of the humerus, and c. compression damage when shoulder braces are used in the Trendelenburg position which pushes the clavicle into the retroclavicular space. Other nerves that can be affected by positioning include the femoral nerve due to extreme lateral rotation and abduction of the hip joint and the sciatic nerve due to stretching along the superior leg when the patient is in the lateral decubitus position (Abdel-Meguid and Gomella, 1996).

In addition nerves may be injured during the surgery itself either due to direct mechanical injury or monopolar electrosurgical current. In this regard, the nerves most susceptible to damage in urological laparoscopy are the obturator nerve during pelvic lymphadenectomy and the genitofemoral nerve during radical nephrectomy/nephroureterectomy.

The diagnosis is invariably made postoperatively. Upon awakening from anesthesia the patient complains of weakness or inability to contract the affected musculature, paresthesias, and/or anesthesia of the innervated skin areas.

Mechanical or electrosurgical injury to a nerve during laparoscopy is often recognized intraoperatively. A common example is transection of the obturator nerve during a pelvic lymphadenectomy. A neurosurgical consult can be obtained and the nerve can be repaired with 6-0 suture using an open incisional approach.

In contrast, nerve palsy due to positioning is recognized postoperatively, often in the post anesthesia recovery room. The medicolegal issues associated with this complication are always significant. As such, from both a medical as well as legal aspect, as soon as a patient calls the surgeon's attention to a possible nerve injury, a neurology consult should be immediately obtained. Neurological examination with possible nerve conduction studies to document acute damage is important. Physical therapy may facilitate recovery. However, recovery in these cases, if it does not occur within the first few postoperative days, is often slow, requiring months.

Prevention is paramount. Accordingly, if the arms are to be at the patient's side, they should be pronated to protect the brachial plexus. If the patient is to be in a lateral decubitus position, all bony prominences should be padded (i.e. hip, knee, and ankle on the downside leg) and padding beneath Velcro straps should be placed on the upside hips and shoulders. Shoulder braces should not be used. Extreme abduction of the hip is also to be avoided. Padding must be checked each time the table position is changed. Lastly, as with all areas of laparoscopy, judicious use of coagulation current and knowledge of the anatomy are key to avoiding nerve injury during the procedure.

D. Complications related to exiting the abdomen:

1. Bowel entrapment

During removal of laparoscopic ports and release of the pneumoperitoneum, omentum or bowel may be entrapped at one of the port sites. If unrecognized, there are no immediate signs at the time of finishing the procedure. Early in the postoperative period, usually on the second or third postoperative day, ileus and specific port site point tenderness develop.

The treatment is laparoscopic. The pneumoperitoneum is re-established, via one of the unaffected port sites and three ports are replaced each in the unaffected areas: one for the camera and two for grasping forceps. The entrapped bowel is visualized and an atraumatic bowel clamp is placed on the bowel on either side of the area of herniation. Once this is done, the skin of the affected port site is carefully opened. The normal bowel on either side of the entrapped bowel can be grasped with an atraumatic bowel grasping forceps. Now the surgeon can manually reduce the bowel into the abdominal cavity. The bowel in between the bowel clamps can then be carefully inspected and if it appears viable, which is usually the case, it can be left in place and the port site closed. Rarely, is a formal bowel resection and anastomosis required.

This particular problem is almost invariably a technical error. Indeed, most laparoscopic ports have a hole drilled into the side of the port, within a few millimeters of the end of the port's shaft. This hole is there to equalize the pressure in the port and the abdomen as the port is pulled out of the abdomen, thereby precluding any bowel from being withdrawn with the port. Furthermore, if each port site is endoscopically inspected at the time of cannula removal, any bowel or omentum that may have entered the port site can be readily identified and pulled back into the abdominal cavity. When the last, endoscope bearing port is removed, if it is a ≥ 10 mm port, the assistant should pull up on the closure sutures and the surgeon should back the cannula out of the wound and up onto the shaft of the endoscope such that the endoscope leaves the abdomen last; thereby again visually assuring that no bowel is in the port site incision. If the last port to be removed is a 5 mm port, then the assistant can back out the cannula with the endoscope slightly leading the cannula such that the tract is clearly visualized and the endoscope again leaves the tract last.

2. Bleeding at the sheath site

Blood dripping from the port entry site and onto the underlying abdominal viscera is the first sign of this problem. The exact site of hemorrhage is determined by cantilevering the trocar into each of the four quadrants and noting which positioning of the trocar tamponades the bleeding.

Definitive therapy for this problem can be undertaken in one of three ways. The simplest method, albeit the most costly, is the insertion of a curved electrosurgical scissors or forceps through another port; this instrument can be articulated up into the port site in order to electrocoagulate the bleeding site. The least expensive method is to suture the area of hemorrhage. This can be accomplished by insertion of a straight Keith needle with a 0 absorbable suture from the outside of the abdomen at one side of the affected quadrant and then grasping the needle with a laparoscopic forceps and pushing it from inside the abdomen at the opposite side of the affected quadrant until it can be recovered on the surface of the abdomen (Figure 18). This broad suture is then tied over a bolster on the abdominal surface; the port can be used throughout the procedure. Alternatively, various port closure devices (e.g. Carter-Thomason device) may be used to similarly pass a suture on either side of the defined quadrant in order to secure a suture over an extra-abdominal bolster and thereby to control the bleeding (Ortega, 1996).

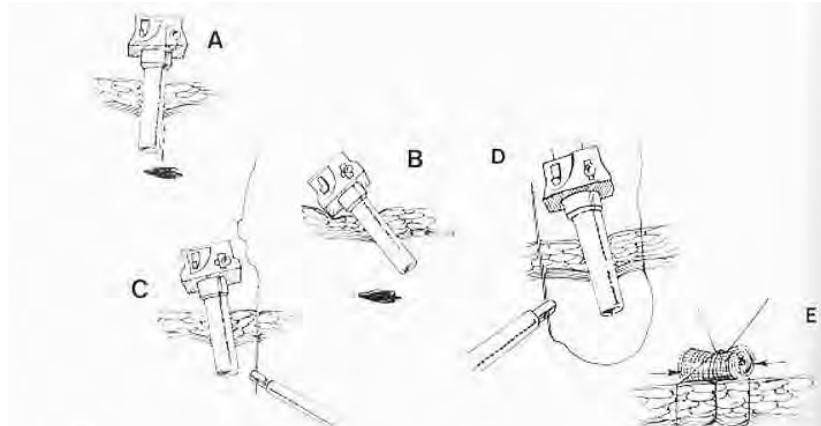


Fig 18 A, Bleeding at the sheath site. B, Trocar can be cattilevered into each of the four different quadrants to identify the source of bleeding. C and D, Straight Keith needle may be used to traverse the site of bleeding. E, Suture is tied down over a gauze bolster. (From Clayman RV, McDougall EM (eds): Laparoscopic Urology. St. Louis, Quality Medical Publishing, 1993)

This problem can often be avoided by routine transillumination of the abdominal wall prior to trocar placement so large surface vessels can be avoided. Also, all non-midline ports should be situated at least 5 cm off of the midline in order to avoid the inferior epigastric vessels. In addition, the routine spreading of the subcutaneous tissues of the proposed port site with a blunt clamp (e.g. Kelly) is also helpful. Finally, careful laparoscopic inspection of the peritoneal surface prior to each secondary port site placement is also helpful to identify the area of the inferior epigastric vessels as well as any overlying peritoneal vessels, which can then be avoided.

3. Acute hydrocele

When significant amounts of irrigation fluid are used during a laparoscopic case in a male, it is not unusual for this fluid to accumulate in the scrotum if the patient has a patent processus vaginalis or small hernia. The problem is usually not recognized until late in the first postoperative day when the patient is ambulating. The scrotum enlarges noticeably and there may be dull aching scrotal discomfort.

Direct visual inspection and transillumination suffice to make the diagnosis of free fluid within the scrotum. If there is concern that there may be underlying testicular pathology, such as a torsed testicle, then a scrotal ultrasound can be obtained. However, in the latter case, the pain is usually of greater intensity and more sudden in onset.

The treatment for this problem is simply observation and scrotal support. Reabsorption of fluid occurs within a week.

Aspiration of irrigation fluid at the end of the procedure may help decrease the occurrence of this problem..

4. Scrotal and abdominal ecchymosis

This is another problem that may not become apparent until the second postoperative day. On occasion it may be seen in the labia majora of female patients undergoing the retroperitoneoscopic approach. It is usually a result of

delayed bleeding from one of the port sites, or can result from tracking of blood from the retroperitoneal space. There are no specific symptoms; but the purplish discoloration of a large area of the skin surrounding a port site is very disconcerting to the patient and family. Indeed, with pelvic ports, the discoloration in the male patient may involve the scrotum too. There is no specific treatment other than observation and reassurance. The purplish discoloration will eventually turn yellow and then disappear. The patient should be informed of these expected changes in "color" to preclude further alarm. The best method of prevention is to perform a meticulous closure of each port site and to observe each port entry site after port removal to check for any evidence of bleeding.

E. Postoperative Complications

1. Pain

Pain may be localized or diffuse. If postoperative pain is limited to a port site, it may be secondary to herniation (immediate or late) or infection (late). Localized pain combined with a subcutaneous bulge may indicate a rectus sheath hematoma, bleeding and hematoma formation at a port site, or palpation of the knot of a port site fascial suture in a thin patient.

Early in the postoperative course, port site discomfort is to be expected; however, if it appears to be increasing on subsequent postoperative days, then herniation should be suspected. Immediate severe diffuse abdominal pain may be related to the release of noxious material during the procedure (e.g. cyst fluid in patients with autosomal dominant polycystic kidney disease) or to a bowel injury. Immediate postoperative scapular discomfort may be a result of the CO₂ pneumoperitoneum itself causing some irritation of the diaphragm; unfortunately, this discomfort may be sufficiently severe to mimic the symptoms of a pulmonary embolus. Delayed diffuse abdominal discomfort and the development of peritoneal signs or simply ongoing abdominal discomfort accompanied by a low grade fever may be due to an unsuspected bowel injury; usually, this is the result of an electrosurgical injury and may present as late as 2-3 weeks after the procedure. Of note, these patients may not have a leucocytosis; however, the differential usually shows a marked left shift.

The etiology of localized pain can usually be discerned by the astute surgeon. A fascial knot or hematoma, causing localized port site pain, can be readily palpated; similarly, a port site infection is discernible by the fluctuance and erythema it produces. When none of these signs are present in a patient complaining of localized pain over a port site, a hernia should be suspected; a CT scan will readily reveal the diagnosis.

Diagnostic procedures in the patient with diffuse abdominal pain primarily include a cell blood count to assess for a leucocytosis or left shift and a CT of the abdomen without and with oral contrast. Delayed films or a repeat CT scan a day or two later may be necessary to make the diagnosis of a bowel fistula. On the other hand, diagnostic procedures for the patient with severe shoulder pain include an electrocardiogram and a ventilation-perfusion nuclear scan as well as

arterial blood gases, to rule out myocardial infarction and pulmonary embolism, respectively.

The treatment of localized pain is directed by the diagnosis. As such, for localized pain due to a hematoma or the fascial suture: time, reassurance, and a heating pad are all that is necessary. For a port site hernia, laparoscopic reduction, as previously described, is the next step. For an infected port site, incision, drainage, and appropriate antibiotic coverage is indicated.

The treatment of diffuse pain is guided by the results of the CT scan. For suspected bowel injury, if early in the postoperative course (i.e. the patient is still in the hospital), then re-exploration and surgical correction are indicated. If the bowel injury is detected late and the CT scan shows that it is already confined, then it can be managed as a closed fistula with observation and an elemental or parenteral diet. While this strategy is effective, it often takes months for the problem to completely resolve.

Prevention of most of these causes of postoperative pain merely entails a meticulous, careful inspection of the entire abdomen prior to ending the procedure. The complete release of the pneumoperitoneum may prevent peritoneal irritation and/or shoulder pain. Various methods have been tried, with variable success, to decrease discomfort due to the pneumoperitoneum; these have included, placement of a drain to help expel all of the CO₂, flushing of the abdomen with nitrous oxide at the end of the procedure to expel the CO₂ and replace it with a less irritating gas, and the selective bathing of the surgical site with a solution of a local anesthetic (e.g. Marcaine).

2. Incisional hernia

In the adult population, the occurrence of an incisional hernia is usually confined to port entry sites ≥ 10 mm. However, in the pediatric population, this complication can occur even with 5 mm ports. The patient usually complains of localized discomfort accompanied by nausea and signs of an ileus. Rarely, diffuse abdominal pain and/or signs of a complete bowel obstruction may be present. On examination, there is tenderness and, at times, swelling overlying a port site. A plain film of the abdomen may show an ileus pattern; however, the definitive study is an abdominal CT scan which can actually reveal the bowel protruding above the fascia.

Laparoscopic repair with dissection of the hernia and subsequent intraabdominal closure can be attempted. The method for performing this procedure has already been described under "Complications related to exiting the abdomen" (1. Bowel entrapment). In complicated cases in which a strangulated hernia is suspected or confirmed laparoscopically, open surgical repair is indicated.

This problem is most easily avoided by performing a meticulous fascial suture closure, in all adults, of port entry sites ≥ 10 mm. This should always be done under direct endoscopic monitoring. In children, it is advisable to perform a fascial closure of any port site ≥ 5 mm. The fascial layer is usually closed with an absorbable 0 suture.

3. Subcutaneous emphysema

Subcutaneous emphysema may be a result of prolonged laparoscopic procedures and/or leaking port sites. Rarely, it is also associated with a pneumothorax or pneumomediastinum. Patients with subcutaneous emphysema develop asymmetric subcutaneous distention accompanied by crepitus. Fortunately, this problem while readily noticeable and disturbing to patient and physician alike, resolves spontaneously within 2 to 3 days.

The problem can be avoided through several maneuvers: working at low pressures (i.e. 10 mm Hg), fixing the laparoscopic cannulas so they do not withdraw into the subcutaneous tissues, and avoiding excessive torquing of the port. The latter results in widening of the passage through the abdominal tissues and compromising the tightness of the seal between the port and the abdominal wall fascia. The problem appears to be more prevalent with prolonged cases (over 200 minutes), the use of 6 or more ports, or with retroperitoneoscopy due to the difficulty in achieving a tight seal between the open access cannula and the retroperitoneal tissues. With respect to retroperitoneoscopy, the use of a open access cannula with an inner balloon and an outer foam cuff (Bluntport, U. S. Surgical Inc., Norwalk, CT) has enabled the surgeon to achieve a tight seal thereby largely eliminating the subcutaneous emphysema that formerly was a common problem associated with this approach.

4. Deep venous thrombosis

While it would seem reasonable to expect decreased venous return and hence increased stasis with concomitant higher risk for deep venous thrombosis in patients undergoing laparoscopy, such is not the case. Indeed, there is no evidence that this complication occurs more often during laparoscopic procedures versus open incisional surgery (Abdel-Meguid and Gomella, 1996).

The signs of deep venous thrombosis include localized calf tenderness with associated swelling. However, most patients with postoperative deep venous thrombosis have a subclinical course. Indeed, unfortunately, the most common clinical scenario is the detection of a deep venous thrombosis only after a patient has developed a pulmonary embolus, following which impedance plethysmography and/or Doppler ultrasonography of the legs is obtained.

The treatment is immediate anticoagulation initially with heparin and then with warfarin. In patients with a pulmonary embolus who are not candidates for anticoagulation, a caval filter is placed under radiographic control.

The problem can to some extent be avoided through the use of pneumatic sequential compression devices and early postoperative ambulation. In the morbidly obese patient or individuals at high risk for thrombosis, the use of unfractionated perioperative heparin (5000 units 2 hours preoperatively and every 12 hours postoperatively) is recommended (Clagett et al, 1995).

5. Wound infections

Superficial wound infections may occur at any of the port entry sites. This problem usually presents with local tenderness, redness, and swelling; rarely, it is accompanied by a low-grade fever. The diagnosis is obvious to patient and

surgeon alike. Incision and drainage of the port site is both diagnostic and therapeutic; antibiotic therapy is routinely administered.

Prevention of this complication is similar to open surgery and includes: attention to antiseptic preparation and sterile draping of the abdominal wall, irrigation of each port site at the end of the procedure, and meticulous closure of the wound.

F. Complications related to general anesthesia unique to laparoscopy:

1. Cardiac dysrhythmias and cardiac arrest:

Cardiac arrhythmias are frequently seen during anesthesia in laparoscopic procedures. The most common arrhythmia is sinus tachycardia (Myles, 1991). Bradyarrhythmias (i.e. A-V dissociation, nodal rhythm and sinus bradycardia) may develop independently, or in combination with tachycardia during the same procedure (Myles, 1991). Conditions leading to development of arrhythmias are carbon dioxide insufflation, hypercapnia, increased vagal tone due to traction on pelvic or peritoneal structures, Trendelenburg position, anesthetic drugs (especially halothane in combination with spontaneous ventilation), preoperative patient anxiety, endobronchial intubation, and gas embolism. In rare cases, asystolic cardiac arrest and cardiovascular collapse may develop.

The role of the anesthesiologist throughout the laparoscopic procedure is of paramount importance. Continuous monitoring of cardiovascular (EKG, arterial BP), and pulmonary (capnometry, in-line oxygen monitor, airway pressures and tidal volume, frequent arterial blood gas analyses) parameters are essential. Invasive cardiac monitoring should be instituted in patients with heart disease (i.e. Swan-Ganz catheter), or when prolonged and complicated laparoscopic procedures are expected in ASA 3 or 4 patients.

As hypercarbia is one of the most common underlying causes of cardiac arrhythmias, it is essential to monitor and control this problem. Overall, hypercapnia can be corrected rapidly by: adjustment of the ventilatory rate and tidal volume, use of positive end-expiratory pressure as needed, and reducing the intra-abdominal pressure to 10 mm Hg. In rare cases, if the hypercarbia cannot be controlled by these maneuvers, then helium should be substituted for CO₂ as the insufflant. However, in this circumstance, a helium specific yoke must be used to connect the gas line to the insufflator.

In the event of cardiac arrest, the surgeon should proceed to immediately desufflate the abdomen and provide cardiac massage while the anesthesiologist administers 100% oxygen and appropriate drug therapy. If a CO₂ embolus is suspected, additional maneuvers, such as turning the patient to a left lateral decubitus position and attempts at aspiration of the embolus are undertaken.

Preventative measures include: avoidance of excessive intra-abdominal pressures (> 25 mm Hg) over a prolonged period of time and avoidance of certain anesthetic agents and combinations (i.e. halothane and spontaneous ventilation). Premedication with atropine may prevent excessive vagal stimulation (Wolf and Monk, 1996).

2. Changes in blood pressure

Hypertension may be caused by inadequate general anesthesia, elevated intraabdominal pressures, hypercarbia, or hypoxemia. Hypotension may be the result of hypoxia, pneumothorax, pneumomediastinum, gas embolus, or hemorrhage (Abdel-Meguid and Gomella, 1996).

Intermittent or continuous non-invasive blood pressure measurements, or, when deemed necessary, invasive monitoring of intra-arterial pressure (e.g. radial artery) is part of all laparoscopic procedures. In the event of a marked change in blood pressure, one of the aforementioned conditions must be ruled out. The initial response of the surgeon, provided that there is neither active bleeding nor evidence for a retroperitoneal hemorrhage is to desufflate the abdomen. In addition to desufflation, therapy specific to an underlying laparoscopic cause may include: CO₂ elimination by increased ventilation, increased oxygen saturation, treatment of an underlying pneumothorax, pneumomediastinum, or gas embolus, and pharmacological (vasodilators or vasoconstrictors) therapy. In the face of transperitoneal or occult retroperitoneal hemorrhage the previously recommended actions should be taken.

3. Aspiration of gastric contents

Aspiration of gastric contents may occur more frequently in patients with a hiatal hernia, significant obesity, diabetics with a history of gastroparesis, and in patients with any form of gastric outlet obstruction (Hanley, 1992). The combination of elevated intra-abdominal pressures from the pneumoperitoneum, morbid obesity, and use of the Trendelenburg position increase the likelihood of this complication (Abdel-Meguid and Gomella, 1996).

The diagnosis is easily made as the problem usually occurs during intubation with associated coughing. The response to suspected aspiration is dependent upon the intubation status of the patient. If the patient is not intubated, his head should be turned sideways and all gastric secretions should be vigorously suctioned. If the endotracheal tube is already in place, it should be left in situ and aggressive suctioning initiated. If aspiration of gastric contents occurs postoperatively, reintubation with mechanical ventilation and positive end-expiratory pressure may be indicated. Neither steroid nor broad coverage antibiotic administration is indicated (Tasch, 1999).

To prevent this problem in high-risk patients, oral or intravenous administration of 10 mg metoclopramide is recommended. This medication may decrease the incidence of aspiration by increasing the tone of the lower esophageal sphincter. In addition, in patients with known gastroesophageal reflux, H₂ blockers or proton-pump inhibitors will reduce gastric acidity and the attendant morbidity if aspiration of gastric contents should occur (Abdel-Meguid and Gomella, 1996; Hanley, 1992). Also, among patients with known gastroesophageal reflux or other predisposing factors for gastric aspiration, a cuffed endotracheal tube should always be placed. Lastly, among these high risk patients, administration of atropine should be avoided as it decreases the tone of the lower esophageal sphincter.

4.Hypothermia

The patient's body core temperature may drop during prolonged laparoscopic procedures, especially if there is leakage of the insufflant around the port sites. The CO₂ that is used is typically neither warm nor humidified. The resulting decrease in temperature may be 0.3°C for each 50 L of CO₂ insufflated (Ott, 1991). The ambient operating room temperature may exacerbate this effect.

The clinical effects of hypothermia are well described. Core body temperatures around the 35°C level may result in: a. increased bleeding tendency due to impaired platelet function, reduced activity of coagulation factors in the coagulation cascade, and enhanced fibrinolysis, b. increase of adrenergic response with vasoconstriction and increased arterial blood pressure, c. prolonged recovery room time due to increased blood gas solubility and decreased minimum alveolar concentration of potent inhaled anesthetics, d. a two-to threefold increase in the incidence of early postoperative myocardial ischemia in high-risk patients, and e. impaired wound healing and increased susceptibility to wound infections.

In general, there are no specific anesthetic symptoms that can be appreciated intraoperatively, except for cardiac arrhythmias. In particular, in extreme cases of hypothermia (body core temperature around 30°C) atrial fibrillation may occur. In this case, if the patient arrests, cardiac resuscitative efforts should be extended as the patient needs to be warmed to 37 °C in order for resuscitative efforts to have their proper impact. The problem is combated by use of warm intravenous fluid and application of active warming systems.

In almost all cases, hypothermia can be avoided. Certainly, warming of CO₂ to physiologic temperatures, especially when a prolonged laparoscopic procedure is anticipated, may be helpful (Ott, 1991). However, just warming the insufflant is likely insufficient and indeed has been associated with an increase in postoperative discomfort. It would appear that the insufflant should be both warmed and humidified in order to counteract the cooling and drying effect of the insufflant. This combination has been shown to result in less postoperative discomfort. This may be supported by intravenous fluid warming and active warming by forced-air systems, circulating warm water mattresses, and radiant heaters (Rosenberg and Frank, 1999).

Summary

Complications, unfortunately, will always be an integral part of every surgical procedure. Clearly, "minimally invasive surgery" although performed through tiny incisions has only added to the complexity of potential complications. Therefore, in order for our patients to reap the benefits of laparoscopy, each urologist must not only strive for technical perfection, but must also obtain, and maintain, an in-depth, current knowledge of the occurrence and treatment of all complications which may be associated with the general and specific use of a laparoscopic approach.

Basic Laparoscopic Instruments

Nondisposable Equipment

Equipment Name	Size (i.e. mm)	Manufacturers
Endotip ports	2 x 10 mm, 3 x 5 mm	15
Reusable trocar	2 x 12 mm (disposable port top)	3, 15
Laparoscope	10 mm, 30 degree 10 mm, 0 degree 5 mm, 30 degree	1, 12, 15, 16, 19
Atraumatic, nonlocking grasping forceps	3 x 5 mm (duckbill)	1, 2, 3, 9, 12, 14, 15, 19
Traumatic, locking grasping forceps	4 x 5 mm	1, 2, 3, 9, 12, 14, 15, 19
Atraumatic, nonlocking pointed tip grasping forceps	1 x 5 mm (dolphin)	1, 2, 3, 9, 12, 14, 15, 19
Electroshield scissors	5 mm reusable handle, replacement scissors	6
Electroshield hook electrode	5 mm	6
Right angle dissector	1 x 10 mm	1, 2, 3, 9, 11, 12, 14, 15, 16, 19
Soft curved angle dissector	1 x 10 mm	2, 9, 15
PEER retractor	1 x 10 mm	9
PEER retractor	1 x 5 mm	9
Angular Triangular Retractor	1 x 5 mm	14
Endoholder (fixed surgical assistant)	1	10
Flamingo grasping forceps	1 x 5 mm	15
Parrot grasping forceps	1 x 5 mm	15
DeBakey forceps	1 x 10 mm	1, 2, 9, 12, 14, 15, 19
Suction/irrigation probe	1 x 5 mm, 1 x 3 mm	1, 7, 9, 15, 16, 19
Romeo needleholder	2 x 5 mm	9
Laparoscopic vascular clamps (bull dog & Satinsky) with applier 12mm	2 of each type	2, 11
Spoon forceps	1 x 10 mm	12, 14, 15
Carter-Thomason closure device	10 mm, 12 mm and 15 mm obturators & needle grasper	8

Nondisposable Equipment

Disposable Equipment

Equipment Name	Size (i.e. mm)	Manufacturers
Balloon tip port – with balloon dilator	10 mm	17
Roticulating Articulating Endoshears	5 mm	7, 17
EndoStitch Device	Suture material 0, 2-0, 4-0, Polysorb & Polydac	17
9 mm Clips & Applier	10 mm (Resusable handle)	7, 17 (3, 7, 18)
Endo GIA stapler	12 mm (vascular and tissue staple loads)	7, 17
Articulating Endo GIA	12 mm (vascular and tissue staple loads)	7, 17
Plastic entrapment (only) sacks	10 mm & 15 mm	7, 17
LapSac (entrapment sack for morcellation)	5 x 2, 6 x 4, 8 x 5, 8 x 10 inch sizes	5
Veress Needle	150 cm	7, 17
Disposable Suction/irrigator	Davol	4
Hand-Assist Device		3, 7, 13, 18
Argon Beam Coagulator	Bovie plates, cords and 5 mm and 10 mm handpieces	
Barrier Nephroscopy Sheet		10

INSTRUMENT COMPANIES

1. ACMI, Southborough, MA www.acmicorp.com
2. Aesculap, Center Valley, PA www.aesculap-usa.com
3. Applied Medical Resources, Rancho Santa Margarita, CA www.appliedmed.com
4. C.R. Bard, Murray Hill, NJ www.crbard.com
5. Cook Urological Inc., Spencer, IN www.cookurological.com
6. Encision, Boulder, CO www.encision.com
7. Ethicon EndoSurgery Inc., Cincinnati, OH www.ethiconendo.com
8. Inlet Medical, Prairie Eden, MN www.inletmedical.com
9. Jarit Surgical Instruments, Hawthorne, NY www.jarit.com
10. Johnson & Johnson, New Brunswick, NJ www.jnj.com
11. Klein Surgical Systems, San Antonio, TX no website
12. Olympus America, Melville, NY www.olympusamerica.com
13. Smith & Nephew, Largo, FL www.wound.smith-nephew.com
14. Snowden Pencer, Tucker, GA www.snowdenpencer.com
15. Storz Endoscopy America, Culver City, CA www.ksea.com
16. Stryker Corp., Kalamazoo, MI www.strykercorp.com
17. U.S. Surgical Corp / Tyco, Norwalk, CT www.tycohealthcare.com
18. Weck Closure Systems, Research Triangle Park, NC www.weckclosure.com
19. Richard Wolf, Vernon Hills, IL www.richardwolfusa.com

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Recommended Training for Urology Residents In Basic Laparoscopy

1. Read the syllabus on Basic Urologic Laparoscopy
2. Basic laparoscopic skills training laboratory session: 3 hours
To include:
Pelvic Trainer A. Beans in a cup: Using two laparoscopic grasping forceps pick up and drop beans into a cup through a hole in the top of the cup. The bean should not be dropped while being transferred to the cup and the cup should not be moved during the dropping of the bean through the hole. A score is given for quantity and quality of the performance of this skill and the multiplication of these two scores is the total score for the skill performance.
Quantity: # of beans dropped
Quality: 0=not able to pick up or drop beans, 1=dropped bean repeatedly or moved the cup during the transfer of the bean, 2=dropped and left bean behind, 3=dropped bean but picked up again and dropped in hole, 4=picked up bean and dropped in hole in one try each time.

B. Align letters and numbers on corresponding grid:
A grid is made and numbers and letters are stenciled into the grid boxes (total 16). Corresponding metal letters and number match the ones in the grid boxes and these are lined up randomly around the periphery of the grid. Using laparoscopic grasping forceps the metal letters and numbers are retrieved and moved to overly the corresponding letter or number in the grid. The metal figure must be positioned exactly on top of the corresponding number/letter in the grid. A score is given for quantity and quality of the performance of this skill and the multiplication of these two scores is the total score for the skill performance.
Quantity: # of placements 16
Quality: # of exactly accurate placements

C. Laparoscopically cut a piece of paper: A piece of paper is marked around the periphery with 1 cm lines drawn 1 cm apart. There is a line drawn around the paper joining the ends of the lines 1 cm from the paper edge. Using a laparoscopic grasping forceps and scissors the lines are cut exactly along the line without going beyond the back line. A score is given for quantity and quality of the performance of this skill and the multiplication of these two scores is the total score for the skill performance.

Quantity: # of cut lines

Quality: # of accurate cut lines; not off the line or past the back limit line

D. Laparoscopic suturing and knot tying: Using a laparoscopic needle holder and grasping forceps pass an SH needle with 6 inches of 0-silk suture through a piece of foam at a specific dot mark and instrument tie 0-silk; five times with square knots. A score is given for quantity and quality of the performance of this skill and the multiplication of these two scores is the total score for the skill performance

Quantity: # of completed needle passes + # of completed ties

Quality: 0=needle entry >3mm from dot, 1=3mm from dot, 2=2mm from dot, 3=1mm from dot, 4=on dot + 0=no knots, 1=mostly air/slip knots, 2&3=occasional air/slip knots, 4=all square knots.

3. Animal Laboratory Session: 4 hours

Perform a laparoscopic nephrectomy in the porcine model with an expert laparoscopic surgeon evaluation; either directly at the time or by expert evaluation of the recorded video of the procedure. In addition, perform a cystotomy and intracorporeally sutured closure. Evaluation by OSAT scoring:

Ablative Laparoscopy	Not Done or Incorrect	Done Correctly 1	Quality (see attached guide)
Establish pneumoperitoneum	0	1	
Place ports	0	1	
Incise line of Toldt	0	1	
Identify anatomic landmarks	0	1	
Secure artery	0	1	
Secure vein	0	1	
Dissect kidney/adrenal	0	1	
Entrap or remove kidney	0	1	
Create cystotomy	0	1	
Intracorporeal suture closure of the cystotomy with LapraTy clips	0	1	
Exit abdomen safely	0	1	
Close appropriate port sites	0	1	
	Score		